Older and Younger Adults' Interactions with 3D Digital Cultural Heritage Artefacts

A Thesis Submitted to The University
of Kent
For the Degree of Doctor of Philosophy
In Digital Arts

By
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June 2015

Abstract

The availability of advanced software allows museums to preserve and share artefacts digitally, and as a result, museums are frequently making their collections accessible online as interactive, 3D models. Since this could lead to the unique situation of viewing the digital artefact before the physical artefact, more research is needed concerning how viewing and interacting with artefacts outside of a museum affects emotional connections to artefacts and how meaning is given to them. Furthermore, users may have varying degrees of technology skills, which could also influence the way they make emotional connections and meaning from interactions with digital artefacts.

This study contributes to existing research by exploring the way older adults (65 years and older) and young adults (18-21 years), two groups of users with diverse technology skills and museum experience, emotionally connect and give meaning to digital artefacts. Interaction with digital artefacts will be through two digital modalities: an Augmented Reality app (AR) on a tablet and 3D models on a website using a laptop. Their subsequent viewing of the physical artefacts will also be examined. Video recordings and questionnaire data, including enjoyment and emotional responses, were analysed quantitatively. Utilising the think-aloud method, participants verbalised their thoughts and feelings while interacting with the artefacts. These comments were analysed both qualitatively and quantitatively to understand how participants construct meaning from their interactions with artefacts.

Results revealed that regardless of age and digital modality, participants made emotional connections with the digital artefacts, and meaning emerged from their interactions. Seeing the physical artefacts after the digital ones still prompted participants to experience emotions; they were not passive when giving meaning to physical artefacts. The results aim to provide insight into how older and younger adults experience two important aspects of a museum artefact experience, emotion and meaning, when first interacting with 3D artefacts on devices outside of a museum.

Acknowledgments

There are many people who have provided their expertise, support, and encouragement throughout my PhD studies, making this a truly positive and memorable experience.

First, I would like to thank my PhD supervisors, Ania Bobrowicz and Jim Ang for their guidance and knowledge throughout this process. I truly appreciate all your feedback on every chapter and paper. You have helped me to become a confident researcher, and without your help, I would not have been able to complete this thesis. I could not have asked for more knowledgeable, approachable, and patient PhD supervisors.

I would also like to thank my PhD Chair Les Walczowski for his support throughout the PhD process, including providing feedback during the PhD Reviews and work as a demonstrator.

Thank you also to EDA Technical Services, especially to Yan Zhang, Ayman El-Kharrat, and Jo Scamp, for all their help with reserving equipment and rooms for my sessions, upgrading my computer, and installing software required for my research.

Many thanks to all the participants, who took time out of their busy schedules to volunteer for my preliminary and main studies, and to the staff at the Powell-Cotton Museum for their generosity.

Thank you to my colleagues in the Digital Arts lab for making every day something I looked forward to. I especially want to acknowledge Sumita Chauhan, Walaa Alharthi, and Panote Siriaraya not only for their support during the PhD process, but also for making the lab enjoyable by balancing out the stress of a PhD with their humour and company.

Thank you to Shailee Pradhan and Mari Imai for your encouragement and advice. I feel so fortunate that we went through our PhD experiences together as international

students studying in Europe. Thank you also to Emilie Bozon for your help with translating one of my references from French to English. To all three, thank you for your generosity and for being a short journey away. You have helped make the last four years so enjoyable.

Finally, I am grateful to my parents, Nate and Adele, my sister Karen, my brother Jonathan, my aunts Lolita and Ofelia, and my grandma Lola for their love and endless support throughout my studies. Words cannot express how much I appreciate all the sacrifices you made for my education, and I could not have accomplished anything without your faith in me. Even though I was studying thousands of miles away from you, I always felt close to home. This thesis is dedicated to you.

Table of Contents

List of Figures

List of Tables

List of Acronyms

AR: Augmented Reality

ARCO: Augmented Representation of Cultural Objects

AREM: Augmented Reality Environment Modelling

CAAT: Circumplex Affect Assessment Tool

FMUSEUM: Form Multimedia System for a European Museum

HCI: Human-Computer Interaction

IQR: Interquartile Range

KARU: Kent Adult Research Unit

NEA: National Endowment for the Arts

NHM: Natural History Museum

UCL: University College London's Museums and Collections

UN: United Nations

UX: User eXperiences

WHO: World Health Organization

Chapter 1: Introduction

Advanced digital technologies are enabling museums to create 3D models of selected artefacts and make them available on their websites. Users now have a unique opportunity to interact with museum artefacts at their own convenience using their personal devices. As the number of visits to a museum website overtakes the number of visitors to a physical museum (Barry 2006), it becomes a likely scenario that visitors might first interact with a museum's digitised collections before seeing the physical artefact, especially if the original is displayed thousands of miles away. The digitised artefacts lack many of the physical contexts that museums provide; physical contexts include the physical space of a museum, interpretations through label descriptions and display methods, and visuals such as supplementary videos or displays (Falk and Dierking 1992c).

The physical context also contains museum websites and the information they offer, such as related events and digital versions of their collections. Artefacts in museums are curated and mostly static; they are displayed at particular angles, located near related objects, and perhaps enhanced using lighting, sound, and narration. It has been established that these factors of a museum environment can influence emotional responses to and the meaning of museum collections and exhibits (Ciolfi and McLoughlin 2012; Schorch 2012; Gadsby 2011), and when viewed without this physical context, digitised copies provided a significantly different experience compared to the originals (Locher, Smith, and Smith 2001; Taylor 2001). However, digital artefacts are still part of the physical museum's collections since they represent physical artefacts displayed in the museum, and if they are accessible online, they are usually connected to a museum's website. Even though they may be experienced outside the museum, they should offer a similar experience to artefacts viewed inside a museum, particularly with regards to emotional connections to artefacts and how meaning emerges from an interaction. Additionally, the decisions made in organising digital artefacts on a website, including background colours and descriptions, as well as a user's ability to navigate a website and locate the digital artefacts, all impact the online experience, and these are similar to decisions made in exhibiting physical artefacts and accessibility in a museum.

Recent research has shown that when viewers interacted with a digital museum artefact outside of a museum, it fostered emotional responses through the meanings given to the artefact (Hogsden and Poulter 2012b). Emotion is considered an important part of understanding artefacts (Taylor 2009) and associated with learning (Kort, Reilly, and Picard 2001; Hooper-Greenhill 1999a), and museums are believed to be experts at 'eliciting emotion' (Weil 1997). Additionally, when a museum visitor interacts with a museum artefact, meaning occurs (Dudley 2012a; Latham 2008; Rounds 1999; Pearce 1994b), which is also related to learning (Hooper-Greenhill 1999a; Falk, Moussouri, and Coulson 1998; Dufresne-Tassé and Lefebvre 1994). Experiencing emotion and meaning during a museum visit can lead to repeat visits and monetary and voluntary contributions (Suchy 2006). Therefore, it is essential that interaction with digital museum artefacts through personal devices, without the physical presence of a museum, results in emotional connections and the construction of meaning, as this can encourage users to visit the physical museum and revisit the website.

Outside a museum, digital artefacts are usually accessed through a museum's website. Museum websites are valuable sources of information to museum visitors, providing information to plan visits, buy tickets online, view images, and access research materials (Marty 2008). However, the technology needed to access digital artefacts, and subsequently, interact with them, may be distracting and confusing to those who are unfamiliar with it. Despite the prevalence of computers and mobile devices in the past ten years, there remains a divide between the technology skills of older and younger adults (Wu et al. 2015), two age groups who also represent distinct types of museum visitors (NEA 2015; Hanquinet and Savage 2012; McIntyre 2007). As museums continue to integrate technology into their offerings, which can attract technology-savvy visitors, it is crucial that current visitors feel included. They should experience emotional connections to digital artefacts and give them meaning. By focusing on older and younger adults and how digital artefacts viewed online can universally affect them, museums can understand how reaching a broad range of visitors can encourage people to interact and spend more time with artefacts (Serrell 1996) using offerings that span generations and abilities (Hein 1998).

Museum audiences are diverse, and so are the types of digital artefacts available online. While there are various formats for digitising artefacts, including images and videos, advanced technologies now facilitate the development of interactive 3D models. Many museums take advantage of 3D technologies by creating 3D models of objects that have many sides. In contrast to paintings and other 2D artworks, many cultural heritage, ethnographic, natural science, and historical artefacts offer details at every angle. Although many museum objects have ties to people and cultures of the past and thus can lead to emotional connections, 3D models are unique in that they allow users to control how they look at each angle of an artefact, thus personalising an experience. This personal interaction can also contribute to their emotional responses. Accordingly, when artefacts are digitised and implemented on devices, viewers should still be able to respond emotionally and give meaning to them. Therefore, the focus of this study is digital cultural heritage artefacts in the form of 3D models. The terms digital artefacts, 3D models, and 3D artefacts will be used interchangeably throughout this thesis to refer to 3D models of museum artefacts.

Unlike physical artefacts and virtual museums, many online 3D artefacts are not exhibited alongside similar artefacts according to a certain time period in a carefully planned display; instead, they are viewed as standalone artefacts on monitors or screens of personal devices (see section 2.2.1). Therefore, it is important to understand responses to interactive 3D models, which enable audiences to potentially view, inspect, and interact with artefacts in 360^{o}, as standalone museum experiences and as online artefact experiences that occur before visiting the physical artefacts in the museum. These are unique situations that have not been possible until recently.

1.1. Context

The process of digitising museum artefacts is both time-consuming and expensive. In the field of 3D digitisation of museum objects, particular emphasis has been placed on cultural heritage artefacts (Di Benedetto et al. 2014; Santos et al. 2014; Singh 2014; Pavlidis et al. 2007; Petridis et al. 2006; White et al. 2004). When museums make the effort to digitise cultural heritage artefacts, it is for several

purposes, among them preservation, reaching a global audience, and unique display methods (Styliani et al. 2009; Arnold 2008). It is for these reasons that digitised artefacts should still be able to resonate with viewers. Online artefacts may be the first impression visitors have of the museum and its collections, leading to some concerns that are timely and urgent. Among them are an understanding of how emotional connections and meaning can result from interactions with digital artefacts that are initially viewed outside of the museum, along with their subsequent effects on viewing the physical artefacts. Previous studies compared original and reproduced artworks to understand participant responses to digital copies; however, participants viewed the originals in the museum and the copies outside of the gallery, with some studies using different groups of participants in each artefact condition (Quiroga, Dudley, and Binnie 2011; Locher, Smith, and Smith 2001) and others only relying on self-reported ratings (Locher, Smith, and Smith 2001; Taylor 2001). Another investigation concentrated on participants' verbalised responses when first interacting with a digital indigenous artefact on a website, but it only discussed participants who might have a connection with the artefact due to their location and the artefact's origin (Hogsden and Poulter 2012b). Additionally, not all of these studies particularly focused on emotional or meaningful experiences. A framework was developed for the purpose of understanding how meaning is given to museum artefacts through verbalised comments while interacting with artefacts (Dufresne-Tassé and Lefebvre 1994), but it has not yet been applied to the digital artefact experience.

When examining museum visitors' experiences, researchers usually concentrated on either the older (Thongnopnua 2013; Elottol and Bahauddin 2011; Kelly et al. 2002) or younger visitors (Shaw and Krug 2013; Gofman, Moskowitz, and Mets 2011; Kelly and Groundwater-Smith 2009). Furthermore, when researchers reviewed museum experiences of visitors in general, they frequently referred to the physical museum experience (Hooper-Greenhill 1999c; Falk and Dierking 1992d). Regarding the use of digital technologies in a museum, older and younger people were mentioned when discussing meaning making, as this form of engagement can potentially lead to learning and interpretation for both age groups, but detailed differences were not explored (Walker 2008). A study that considered online

museum collections only briefly presented media preference differences between older and younger visitors (Negrini, Paolini, and Rubegni 2012). Moreover, Falk and Dierking updated their museum experience model to include digital and online implementations (Falk and Dierking 2012), but they did not specifically focus on viewing digitised artefacts. Interacting with digital artefacts outside a museum requires the use of personal devices such as computers, tablets, and smartphones, and the potential audience may have a wide range of technology skills. However, the body of research associated with viewing interactive digital artefacts before physical artefacts, the resulting emotional connections and construction of meaning, and older and younger adults, is not extensive, despite these two age groups representing distinct technology skills and attitudes towards museums.

1.2. Research questions

This study aims to build on the aforementioned research by exploring how older and younger adults respond emotionally and create meaning while interacting with digital artefacts on different types of digital modalities, including how this affects their emotional connections and the meaning that emerges when subsequently viewing the physical artefacts. The two digital modalities entail the use of a PC and a mobile device, representing two key methods of accessing digital artefacts. The results can provide an understanding of the capabilities of two different types of digital modalities for enabling emotional connections with artefacts and the construction of meaning, along with how this affects the physical artefact viewing experience. This study will address the following research questions:

1. How do older and younger adults emotionally respond to digital cultural heritage artefacts outside of a museum?

   Chapters 3, 4, and 5 describe the methodologies used to select the cultural artefacts, digitise and implement them into a website for use on a laptop and an Augmented Reality (AR) app on a tablet, and establish the procedure for older and younger participants' interactions with the digital artefacts. Due to emotion being an essential part of experiencing museum artefacts, it is

imperative to understand how participants emotionally respond when first interacting with digital artefacts instead of physical artefacts. Chapter 6 presents a quantitative analysis of the amount of time participants spent interacting with artefacts in each digital modality as well as their responses to questionnaires. Two separate questionnaires asked participants to indicate their enjoyment and emotions experienced in response to interacting with the digital artefacts on the two digital modalities. Chapter 8 discusses the implications of the results in Chapter 6.

2. How do older and younger adults construct meaning while interacting with digital cultural heritage artefacts outside of a museum?

   This research question builds on question 1 by understanding how participants construct meaning while interacting with artefacts. Chapters 3, 4, and 5 form the basis of the methodologies used to select the cultural artefacts, digitise and implement them into an AR app on a tablet and a website for use on a laptop, and determine the process for older and younger participants' interactions within the digital modalities. As meaning is derived from the viewer-object interaction, more understanding is needed when the objects are digital. Chapter 7 explains the qualitative and quantitative analyses of the verbalised comments of participants as they first interacted with artefacts in the digital modalities. The implications are discussed in Chapter 8.

3. How does first interacting with the digital cultural heritage artefacts outside of a museum affect the subsequent viewing of the physical artefacts?

   Focusing on the subsequent physical artefacts modality, this question examines how older and younger adults make emotional connections with the physical artefacts and the meaning that emerges. Chapters 3 and 5 describe the methodologies used to select the cultural heritage artefacts and the procedure for older and younger participants' viewings of the physical artefacts. Chapters 6 and 7 examine the results of quantitative and qualitative analyses on participants' emotional connections with the physical artefacts

and their construction of meaning. Chapter 8 discusses the implications of the results.

1.3. Scope and contribution

Museums make their digitised collections accessible using many methods, but the scope of this thesis is digital artefacts without the presence of a museum's architecture and display methods. Therefore, this thesis focuses on digitised artefacts viewed outside a museum. It also does not include virtual museums, which in this study refers to museums that were digitally reconstructed to capture both their architecture and collections (see section 2.3.1). Correspondingly, without much of the physical context of the museum experience, along with little attention towards the social context of the museum experience, this thesis does not aim to provide insight into whether interacting with digital artefacts on personal devices outside of a museum maintains an interactive museum experience, as discussed by Falk and Dierking (1992d).

In addition to Falk and Dierking's museum experience model, there are other frameworks for understanding visitors' experiences in a museum, but the scope of this thesis is the emotional and meaningful experience of viewing museum artefacts. As a result, this study utilises a framework developed by Dufrese-Tassé and Lefebvre (1994) intended for understanding the meaning of in-situ museum experiences of viewing objects. The framework also incorporates emotion. This approach, combined with the use and analysis of questionnaires and the think-aloud method (see Chapter 5), was designed to answer the research questions. Consequently, delving into the range and depth of participants' meanings from their interactions with digital artefacts was not within the scope of this research. However, an in-depth investigation of the range and depth of participants' interactions with physical artefacts was included as part of the preliminary study in Chapter 3 in order to gain an understanding of how museum visitors interact with physical artefacts from the same museum as the digital artefacts.

Technology-wise, museums utilise different methods for digitising their artefacts, and although this study considered several different processes, recommendations for museums looking to create 3D models of artefacts are not provided. The extent of this thesis is to provide insight for museums that have already made 3D models of their artefacts available online, focusing on how emotion and meaning can result from users' interactions with digital artefacts. In contrast to 2D digital artefacts like photographs of 3D physical objects, 3D digital artefacts allow users to control their rotation to see an artefact in 360°, making the digital artefact experience unique compared to not only viewing 2D artefacts, but also viewing 3D physical artefacts in a museum, as these are typically displayed in a fixed position and behind a barrier. Users can customise their own artefact viewing experience, instead of curators or museum personnel deciding how to best showcase an artefact. It is the user who can decide what aspect of a 3D digital artefact to spend more time on and look more closely at through zooming and rotating controls. Even with 2D digital artefacts like photographs, the views of an artefact are pre-determined; one cannot choose another angle or view of an artefact if it is not available. Additionally, the Internet and devices used to access 3D digital artefacts are the main technologies examined, as they are accessible to a wider audience and available outside of the museum. Therefore, technology such as haptics (see section 2.2), which might provide greater knowledge on emotional and meaningful experiences, is not included in this study.

The work described in the following chapters provides insight into how people with typically diverse attitudes towards museums and technology skills emotionally connect with artefacts and construct meaning when first interacting with them digitally, then how this might affect their later viewing of the physical artefacts. While previous research analysed different aspects of this topic, knowledge about this particular combination needs more attention. As such, this study provides contributions for museum practitioners, cultural heritage researchers, and HCI researchers, among them:

- An understanding of the way older and younger adults make emotional connections with digital artefacts when they first interact with 3D models of cultural heritage artefacts outside of a museum (Chapter 6 and 8)

- An understanding of the way meaning emerges when older and younger adults first interact with 3D models of cultural heritage artefacts outside of a museum (Chapter 7 and 8)
- Insight into how older and younger adults experience emotional connections and construct meaning from interactions with digital artefacts implemented on two different digital modalities (Chapter 6, 7, and 8)
- An understanding of how emotion and meaning result from older and younger adults' interactions with physical artefacts after first interacting with the digital artefacts (Chapters 6, 7, and 8)

The preliminary study described in Chapter 3 was initially conducted to explore emotional responses to physical artefacts with the aim of designing a mobile application for use within a museum. The results of this study were presented at two conferences and published as part of their proceedings (Alelis 2013; Alelis, Bobrowicz, and Ang 2013). Based on this study, more important directions emerged that were not apparent at the beginning, and as a result, the focus of this thesis changed. However, the preliminary study's findings were still pertinent. Additionally, the analysis in Chapter 6, along with its methodologies and Discussion, was accepted by a peer-reviewed journal to contribute to existing knowledge of older and younger adults and how they emotionally connect to digital cultural heritage artefacts (Alelis, Bobrowicz, and Ang 2015).

1.4. Structure of thesis

Chapter 2 provides a literature review of previous work that relates to this thesis. The key topics of this thesis are discussed: older and young adults, technologies enabling interaction with digital museum artefacts, emotional responses, and meaning. Additionally, a comparison of digital museum artefacts and physical museum artefacts according to factors that could contribute to viewer responses is presented.

Chapter 3 presents a qualitative preliminary study conducted to understand museum visitors' emotional responses to artefacts in a physical museum. Interviews with 20

participants were analysed to find categories for the artefacts chosen by them, as well as themes describing their emotional responses to certain artefacts.

Chapter 4 builds on the results of the previous preliminary study and explains the methods used to select, digitise, and implement the 3D artefacts into two digital modalities for the main study. Owing to various options for interacting with digital artefacts, two different digital modalities will be investigated: specifically a website on a laptop and an AR app on a tablet. These represent two key methods of accessing digital artefacts outside of a museum.

Chapter 5 describes the study procedure for the main study involving 20 older and 20 younger participants, which required them to verbalise their thoughts when first interacting with the artefacts in two digital modalities, then the physical artefacts. Focusing on older and younger adults will provide the background needed to understand users with different technology skills. Additionally, all three artefact modalities will be viewed outside of a museum to ensure consistent environments. As a growing number of museums make 3D digital artefacts accessible online due to advanced technologies, the likelihood that audiences will interact with digital artefacts as a standalone experience or before visiting a physical museum also increases. In this main study, however, the physical artefacts will not be shown in a museum; instead, they will be shown in the same conditions as the digital artefacts. Due to museum studies that indicated that some emotional responses were influenced by the physical museum and its environment (see section 2.4.2), it was imperative that the physical artefacts were viewed outside of the museum so that the physical museum and its environment did not affect research outcomes.

Chapter 6 explains the results of a quantitative analysis of the main study. The amount of time participants spent interacting with artefacts in each modality, as well as their responses on three separate questionnaires, were the focus of this analysis. The questionnaires asked participants to indicate their enjoyment and emotions felt in response to interacting with the digital artefacts on an AR app using a tablet and on a website using a laptop, and then viewing the physical artefacts.

Chapter 7 presents the results of qualitative and quantitative analyses of the main study. In this analysis, emphasis was on how meaning emerged from interactions with artefacts through participants' transcribed comments as they first interacted with digital artefacts on a website using a laptop and through an AR app using a tablet, then viewed the physical artefacts.

Chapter 8 discusses the implications of experiencing emotional connections with interactive digital artefacts and giving them meaning when users have yet to view the physical artefacts. This includes how this may affect a subsequent encounter with physical artefacts in a museum, a comparison of the digital modalities, and age differences between the older and younger participants. Limitations of the study are also identified.

Chapter 9 provides conclusions on the work carried out in this study and suggests future work.

Chapter 2: Literature Review

Before undertaking a study focusing on older and younger adults and how emotions and meaning emerge from their interactions with digital artefacts, it is necessary to review relevant research. This chapter focuses on why older and younger adults are an important age bracket for museum and technology research, the opportunities for interacting with digital artefacts offered by museums, comparisons between digital and physical museum objects, and the importance of emotion and meaning when interacting with museum artefacts.

2.1. Older and younger adults

One of the benefits of making artefacts accessible online is that they become available to anyone with an Internet connection. Digitised artefacts accessed using different devices such as computers, tablets, and smartphones may affect user responses, especially if there is a disparity in technology knowledge. This could affect the way users interact with and understand digital artefacts. Due to the accessibility of digital artefacts, two distinct age groups are of interest: older and younger adults.

2.1.1. Older adults as museum visitors

The definition of older adults as a demographic of museum visitors varies according to research in different countries. The North East Museums Hub in the UK organised a comprehensive study of UK museum visitors and reported on data from 2000 to 2006. They found that 27% of museum visitors are mainly aged 55 and over (McIntyre 2007). A more comprehensive report published by the National Endowment for the Arts (NEA) in the US analysed participation in the arts from 2002-2012. Their results revealed that adults aged 75 and over were the only group whose attendance at art museums and galleries increased over the decade, and people aged 55 and over had the highest arts participation rate at 35.7% in 2012 (NEA 2015). These statistics show that older people enjoy visiting museums and spending free time there. Yet, there are still aspects of museums that can be improved for

them. Researchers explored museum accessibility and exhibition methods from the perspective of older visitors aged 65 and over, with seating, building design, label readability, lighting, noise, and crowds all contributing to their concerns (Kelly et al. 2002). Similarly, Elottol and Bahauddin (2011) investigated the relationship between 21 museums' pathway designs and older visitors' satisfaction in museums using participants who were at least 65 years old. Not surprisingly, statistical analysis indicated that poor interior design and planning lead to lower satisfaction with the quality of a museum's design. Consequently, older people may be willing to accept accessing museum collections from their homes if it increases their comfort and leads to a satisfactory experience. Outside a museum, people aged 42-105 were participants in a study that demonstrated that handling museum artefacts could be used to help older adults in retirement communities access their memories and improve their moods (Smiraglia 2015). This study indicates that interacting with museum artefacts outside of a museum can be beneficial for older people who are interested in museum collections and may not be able to visit frequently.

Older people and museums have also been the focus of studies related to well-being, happiness, and healthy aging. Jivraj, Nazroo, and Barnes (2012) focused on older people aged 50 and over in their English Longitudinal Study of Aging, conducted from 2002-2010. Through questionnaires and interviews, they found that aging is linked with increased loneliness and social detachment, including within the cultural engagement domain. Since museums and similar institutions provide opportunities for older adults to interact with other adults, docents, and volunteers, it is important that museums remain a part of older people's lives, as social engagement contributes to successful aging (Jivraj, Nazroo, and Barnes 2012).

Another benefit of visiting museums is that it can have positive impacts on a person's well-being, happiness, and health, as the Happy Museum Project determined from its studies measuring and valuing audiences' happiness after visiting museums (Fujiwara 2013). The Happy Museum Project (2013) identified approaches that museums should consider to foster well-being; these include creating a welcoming environment for visitors, integrating creativity and imagination, being upfront with well-being benefits, and engaging with the community. Volunteering in

museums also encouraged happiness and healthy aging. As volunteers and employees at museums, older adults recounted how their experiences made them feel worthwhile and fulfilled. They were positive influences within the community and they also made new friends (Silverstein, Garcia, and Landis 2001).

Happiness and health are synonymous with well-being and are evidence of the cultural value of museums for individuals (Scott, Dodd, and Sandell 2014). Additionally, a study by Crotts and van Rekom (1998) highlighted that visitors' personal values for visiting a museum are identified through their behaviours and motivations for their visits. When museums met these goals, visitors experienced positive outcomes such as enjoyment, relaxation, and return visits. Fujiwara and MacKerron (2015) concluded that arts and cultural activities have positive effects on people's happiness and relaxation. Interestingly, they also found that people who experience arts and cultural activities alone have the greatest positive effect not only on happiness, but also relaxation. Similarly, Binnie (2010) found that museum visitors' anxiety levels decreased after viewing artwork; thus, their experiences positively affected their well-being.

Outside a museum's walls, museums utilise outreach programmes to assist with increasing well-being for those who are unable to visit in person due to health issues. Through subjective measures of happiness, wellness, interestedness, confidence, and optimism, Johnson et. al. (2015) demonstrated that art-viewing and museum object handling have both been shown to increase well-being for people with dementia and their caregivers, regardless of whether individuals experienced art-viewing or object handling first. Likewise, art and cultural activities outside of the museum can have long-term benefits, including friendships and improved relationships between care staff and residents, which result from increased morale, self-confidence, and social connections, all of which are linked to well-being and social inclusion (Roe et. al. 2014). Thomson and Chatterjee (2014) recognised the need for a standardised method of measuring the impact of museum, arts, and heritage services on the health and well-being of audiences and developed the Museum Well-being Measures toolkit. Consisting of pre-test and post-test survey questions, the toolkit compared

how museum activities and visits made participants feel, and survey scores indicated that there were increases in well-being and decreases in negative well-being.

If older adults can access museum collections on their own time through technology, then there is potential for healthy aging and well-being through the digital museum experience.

2.1.2. Younger adults as museum visitors

In the North East Museums Hub's study, UK visitors who were 24 and under were the least likely to visit a museum, representing 13% of visitors (McIntyre 2007). This representation has not changed in the ensuing years, as the NEA report revealed that younger people aged 18-24 consistently had the lowest representation for arts-based events (art museums, galleries, and historical places) out of all the visitor age groups, but especially when compared to adults aged 65 and over. In fact, the younger group's attendance percentage decreased from 2002 to 2012 (NEA 2015). This can perhaps be attributed to younger people's perception of museums as having 'rows of boring glass cabinets filled with items to be viewed but not touched' (Kelly and Groundwater-Smith 2009). This perception, along with their belief that museums can be restrictive, prevents younger people from viewing museums as places of leisure (Hanquinet and Savage 2012). However, when young people do visit museums, they want a closer examination of artefacts and opportunities to make emotional connections and meaning when interacting with a museum's collections and exhibits (Kelly and Groundwater-Smith 2009). They also want engaging experiences, interactivity, and individualised learning (Shaw and Krug 2013; Gofman, Moskowitz, and Mets 2011). Online technologies may be the key to enabling these experiences for a younger audience. Farrell and Medvedeva (2014) recognised that younger people aged 18-29 'opt for new modes of participatory engagement' when visiting museums and other forms of culture, and this is supported by the findings of the NEA. Engagement 'requires one to extend emotional involvement or make a commitment to something'; this was one of the recommended aspects when designing virtual museum spaces for young people aged 15-25 (Shaw and Krug 2013).

Through their exhibitions, technologies, and programmes, museums encourage engagement and participation from their audiences, especially by young people. Arriaga and Aguirre (2013) discussed a programme at the Tate Britain that focused on students' comments and reflections on exhibits and art. The Young People's Programmes, in which educators led museum tours for young people, allowed visitors to consider their own interpretations of art. The educators interacted with young people by posing questions related to looking at the works of art. When engaged in this method, young people used their imaginations and built upon their prior knowledge to contemplate the meanings of artworks. This signified that young people's interpretations were valued by museums; by implementing this programme, young visitors were not just looking at art, they were also urged to construct their own meanings during their visits.

Relatedly, the Musée d'Orsay also offered programmes that focused on inspiring young people to provide their own interpretations and meanings to works of art (Johanson and Glow 2012). In particular, the programme 'Ranc' Art' was designed in response to young people's perceptions of museums as boring places they are required to visit as part of their school's curriculum. This programme facilitated meetings between young people and young artists to give them another view of what it means to be an artist, as well as offered discussion groups where young people could freely ask questions and talk about their various interests. These discussions revealed that young people's interests actually included the museum itself, as they had questions about references to paintings and decisions about paintings' display methods.

As museums look for new methods of building their younger audiences, they naturally utilise social media and technology. Fois (2015) identified the role of the prosumer, an amalgamation of the words 'producer' and 'consumer', which is positively 'influencing the cultural sectors and specifically heritage institutions'. She recommended that museums and cultural institutions focus on digital methods that allow 'users to become producers', citing several museums that have implemented interactive online experiences. For example, the Institute of Contemporary Arts in London offered 'unique online commissions', and the Museum of Modern Art in

New York established the website MoMA Teens, which resembles the social platform Tumblr (Fois 2015). By using formats that are already familiar to young people, such as Tumblr and YouTube, museums can encourage young people to visit their websites, contribute content, and share their ideas and opinions.

Jewitt (2014) examined how museums incorporate digital technologies into a visit and how this contributes to meaningful experiences. One example is a weather installation at London's Tate Modern, which prompted visitors to record their experiences and interpretations using their own cameras. Visitors then shared their videos and photographs on social media sites such as YouTube and Flickr. This, along with Tate Modern's own YouTube channel, facilitated continued engagement with the installation, as well as with other people. In some cases, the original installation had been altered in its digital format through the addition of people, soundtracks, and even political messages. As a result, the meaning of the original also changed, but experiences were still meaningful. Another installation involved mobile devices aimed at students visiting the D-Day War Museum in Portsmouth. The aim was to allow visitors to construct and share their own interpretations of exhibits through taking photographs, recording sounds, and adding descriptions to objects. These contributions were also made available for students to access online after their visit. Through the use of mobile technologies, students spent more time engaging with objects and remembered information, indicating that the experience was meaningful (Jewitt 2014).

As these studies show, when given the opportunity to use technology to access museum content and provide their own contributions, young people are engaged with museum collections and have meaningful experiences.

2.1.3. Difference in technology skills

The older and younger people's generational divide in museum attendance is mirrored in their technology use, as those who grew up with technology are often referred to as 'digital natives' and those who were 'not born into the digital world' but are interested in or use technology as 'digital immigrants' (Prensky 2001).

Concerns about differences in their technology skills are still relevant today (Wu et al. 2015). As more museums start to offer their collections online, these two groups of visitors may offer the most insight into the effects of interacting with digital artefacts on personal devices.

2.1.3.1. Technology and older adults

Older adults aged 65 and over, who are comparatively unfamiliar with newer technologies or whose computer use is limited (Olson et al. 2011), may not be as adaptable to new technologies as those who grew up using computers. While older people are more hesitant to try new technologies compared to younger people, there was little evidence that they were opposed to using technology in general. They are more selective in the technologies they choose to use, but if it can make their lives easier, they will use it more frequently (Olson et al. 2011). This is encouraging since online museum collections would enable older people to virtually visit a museum from the comfort of their home using familiar technology. This can help those who are housebound or not well enough to travel. A study involving participants aged 58-72 found that older adults already use the Internet to seek health-related information (Harrod 2011), and tablets are considered tools to support the elderly or disabled and help them be more independent (Castro et al. 2011).

Still, a study in Italy showed that older people aged 60 and over (32.5%) were not as likely as people aged 40 and younger (68%) to access additional museum content online via a PC, and when accessing content using a mobile device, the number dropped to 15% for older people (Negrini, Paolini, and Rubegni 2012). A recent survey at the Natural History Museum (NHM) in the UK agreed with this, indicating that older people aged 65 and over represented only 2% of smartphone owners and 5% of tablet owners out of the visitors surveyed. However, older people were six times more likely to use a tablet, not a smartphone, while inside the museum (Fusion 2013). This data demonstrates that older people who are at least 65 are not opposed to using new technologies to interact with museum collections. Even though older people already comprise a key sector of museum audiences, digital technologies can

provide them with opportunities to extend their museum visit or view artefacts at their own pace without having to travel to the museum.

2.1.3.2. Technology and young adults

Younger people, particularly US students from primary school through university, are more likely to have grown up with computers and video games (Prensky 2001). Therefore, they may be more inclined to see artefacts online and prefer to interact with them as opposed to just view them behind glass as in most museums. Since laptops and mobile devices are considered learning devices in classrooms (Sun, Yang, and He 2014; Norris and Soloway 2011) and home-schooling (Trentin et al. 2015), personal devices are integrated into almost every aspect of young people's lives from an early age. Moreover, mobile devices can support learning in universities (Jacob and Issac 2008). The NEA reported that about 8% of Americans surveyed in their report used technology to access art. Here, art encompassed paintings, sculpture, graphic design, and photography. In particular, people aged 18-34 were twice as likely to use mobile devices to access art than older adults aged 65 and over (NEA 2015). This implies that young people are not opposed to viewing museum collections as long as they have some control.

The NHM survey in the UK indicated that almost 30% of younger people under the age of 24 owned a tablet and almost 40% of them owned a smartphone. Visitors used their smartphones to look up information about exhibits and objects, in addition to directions and opening times. The NHM report concluded that museums should offer basic visitor and exhibit information on mobile devices instead of 'trying to accomplish too much' by including social media, games, and interpretive information (Fusion 2013). Based on this data, museums can appeal to a younger audience by offering more interactive content through smartphones and tablets, but this content has to be helpful, engaging, and focused. Online digitised artefacts can enable young people to access museum artefacts from home, school, or on the go and interact with artefacts in novel ways using their own personal devices. When young people use their personal devices to interact with digital artefacts, they will not be confined to a museum space (Hanquinet and Savage 2012) and instead can make

their own decisions as to how and where to look at artefacts. Users can use different platforms to access digital artefacts, including their desktop computers, laptops, smartphones, or tablets, and these technologies allow them to zoom in on and rotate artefacts. In a museum, artefacts have been carefully positioned in glass cases and are typically organised according to their geographic location or time period. With digital artefacts, users can customise their experiences and examine, rotate, or zoom in on artefacts that pertain to their coursework while using technology in the classroom. Users can even curate their own online museum experience by focusing on artefacts that have no common links except for their colours, shapes, or materials. With digital artefacts, the only limitation to how digital artefacts are viewed online is the imagination. As a result, the experience could motivate young people to visit a museum and see the physical object.

2.1.3.3. Initiatives to encourage online visitors to visit physical museum

As online audiences, young people are different not only from older people, but also from highly trained educators. In terms of their education and skills, Brown, Gerrard, and Ward (2005) compared educators to researchers and students to the general public. Therefore, there needs to be an effective method for designing digital museum content for these distinct audiences. Websites provide the structure necessary for targeting different audiences by offering different ways to show the same information. As such, there are three elements that websites should consider: 'multiple points of entry, connecting storylines, and layered content' (Brown, Gerrard, and Ward 2005, p. 2). When museum websites give users a degree of freedom over how they access information, they provide audiences with different experiences each time they visit, as well as motivation to revisit the website and visit the physical museum.

Schweibenz (2013) agreed that the online and physical museum experiences are different because visitors have different motivations for visiting each type. While both offer learning opportunities, it is the Internet that is typically used for sharing resources and communicating with people, both friends and strangers, around the world. Likewise, visiting museums in person is more of a social event with friends

and family, whereas users are typically alone when they visit online museums (Schweibenz 2013). When online visitors share their museum experiences with others through social media or when meeting friends and family in person, this can act as a positive endorsement for a museum, leading to in-person visits as a group.

Arts Council England (2013) published a report on how arts & cultural organisations use technology. Findings indicated that digital technologies such as the Internet are used by organisations to reach a more diverse, international, and younger audience, and while these technologies may be linked to a current exhibition, they presented unique experiences to visiting the physical museum. Examples of these implementations were in The Tate Britain in London, which offered an online exhibition called 'The Gallery of Lost Art' that provided stories of art that has disappeared, and The Wordsworth Trust in Grasmere, which developed a smartphone app to be used alongside an art exhibition. Museums also used Twitter to publicise their digital content, share behind the scenes images, and interact with audiences. A positive outcome from the Arts Council report was that a majority of organisations disagreed that digital technologies and making content available online would lead to a decrease in physical museum attendance (Arts Council England 2013).

Another technology used at the Tate museums in London was ArtMaps, an app based on crowdsourcing that utilised Google Maps to provide an innovative method for visitors to find, move, and annotate artworks (Giannachi et. al. 2015). Feedback from users indicated that they considered ArtMaps as a complement to the physical museum experience because they could see visualisations of artworks on the maps as well as in the museum. They could also interact with other users of ArtMaps by reading their annotations, seeing routes taken on the map, and posting opinions on social media. Consequently, this motivated users to visit the physical museum to look at the original works of art.

2.1.3.4. The online visit as a standalone experience

While it is important that technology can motivate both older and younger audiences to visit a physical museum, the online museum experience is increasingly

acknowledged as a valuable museum experience on its own. As museums continue to offer digitisations of their collections, a greater understanding of the online museum visit and its audiences are needed. Hazan (2001) examined three different models of museum websites to understand how museums communicate their online identities: online databases, virtual museums with no physical counterpart, and web-based contemporary art. She described the advantages of standalone online museums, including the cost benefits when museums only construct their museums virtually, remote access to collections from all over the world, and the accessibility of more artworks and objects online compared to the limited collections that can be displayed in physical museums at one time. She claimed that viewing artefacts online can be just as compelling as other second-hand experiences such as watching television and reading books in familiar places such as homes and classrooms. Viewing digital collections is an 'enchanting technological process of networked art' where viewers can still 'appreciate the craftsmanship of the new medium' (Hazan 2001, p. 12). Even though artefacts are digitised, they represent real objects, and their digitisation process gives them an enchantment, or sense of awe, because this process is complicated, which many people do not understand (Hazan 2001).

The online museum experience can be a separate and different experience from visiting physical museums, but they are similar in that they have diverse audiences. Not everyone has the same reasons for visiting physical museums, and similarly, audiences all over the world have different motivations for accessing museum websites. Peacock and Brownbill (2007) focused on audiences' diverse needs and behaviours when they proposed a new model for conceptualising museum website site use. Based on their research, four levels representing knowledge domains make up their model: Market, User, Interaction, and Product. After testing their model on eight different personas, they concluded that museums should follow certain principles when developing websites. These include acknowledging that there is a market for the online experience, clarifying and planning for site goals, designing for the virtual space, not a copy of the physical museum, and testing with target users at every development stage. These decisions can have positive impacts on relationships between users and museums, including continuous online visits due to visitor satisfaction. Websites also enable social interactions that may not be possible in

physical museums. Bandelli (2010) suggested that it is more common for people who do not know each other to have spontaneous conversations virtually than in person because there are no physical constraints. These conversations can lead to a greater understanding of museum collections, but Bandelli also anticipated that as technology becomes more common and people become used to them, it might become difficult to start conversations with strangers as social barriers might arise.

2.1.4. Scope of older and younger adults

As evidenced by this review of older adults in museums and their general technology background, the definition of an older person usually spans a broad range of ages. On a global scale, the United Nations (UN) published a report in 2013 that classified those who are aged 60 or over to be older people (UN 2013). The World Health Organization (WHO) acknowledged that many developed countries agreed that people aged 65 and over are defined to be an older or elderly person (WHO 2015). Ages for older people can further be categorised as 'young old' (65-84) and 'oldest old' (85 and over) (Tomassini 2005). This data, along with the discussed research that included participants aged 65 and over, guided the focus of this study to similarly be older adults who are at least 65 years old. For young adults, 18 is the age when they are first considered adults in many countries; for example, this is the age when people can legally vote in a majority of countries, including the UK and US. It is also when they typically attend university and move away from home, allowing them more freedom to choose how to spend their free time. Moreover, students usually graduate university within 3 or 4 years, propelling them to seek employment around the age of 21. As such, younger adults in this study will concentrate on people aged 18-21. Since research has indicated that laptops and mobile devices are used for learning in schools and universities (see section 2.1.3.2), young people aged 18-21 are either still formally pursuing their education or have just recently left. This age bracket has likely used laptops and tablets, representing a typical 'digital native'.

Serrell (1996) and Hein (1998) both recognised the need for museums to make their exhibits universal in order to encourage all types of visitors, spanning different

generations and abilities, to interact and spend more time with artefacts. This is even more applicable for digital artefacts since the online audience may span a broad age range and have very diverse technology backgrounds. Due to these two age groups having different opinions of museums as well as contrasting technology skills and knowledge, it is appropriate to understand their interactions with 3D artefacts.

2.2. Modalities enabling interaction with digital museum artefacts

In museums, visitors interact with exhibits and collections through various Human-Computer Interaction (HCI) systems such as mobile guides (Chang et al. 2014; Fevgas, Tsompanopoulou, and Bozanis 2011; Tillon, Marchal, and Houlier 2011; Wang et al. 2009; Walker 2008; Rocchi, Stock, and Zancanaro 2006; Goren-Bar et al. 2005), standalone kiosks (Klindt et al. 2012; Cosley et al. 2008; Boehner et al. 2005), installations (Kim, Lee, and Do 2011; Boehner, Sengers, and Gay 2005), and even mobile games on personal devices, specifically smartphone and tablets (Chatzidimitris et al. 2013). Interactive technologies in museums can encourage emotions and meaning-making, resulting in learning and engagement (Keitel 2012; Walker 2010). Additionally, haptics technology can enable users to touch digital museum artefacts in order to feel 'the sensation of shape and texture' (McLaughlin et al. 2000). This technology has also been implemented in museums through different installations (Osorio et al. 2011; Figueroa, Coral, et al. 2009).

Some HCI implementations encouraged visitors to reflect on their experiences (Cosley et al. 2008; Boehner et al. 2005) and provide emotional responses to collections (Rocchi, Stock, and Zancanaro 2006; Goren-Bar et al. 2005), all of which helped personalise their visit. Interacting with museum collections through technology can offer a more engaging museum experience compared to visitors who did not utilise any technologies (Kamal Othman, Petrie, and Power 2011), but using digital modalities in a museum can initially be frustrating, may distract the viewer, or interfere with the museum visit (Chatzidimitris et al. 2013; Tillon, Marchal, and Houlier 2011; Damala et al. 2008). These technologies were designed to supplement a physical museum visit and offer different types of interactive elements, including games and quizzes. Current applications enable interactions that focus on artefacts

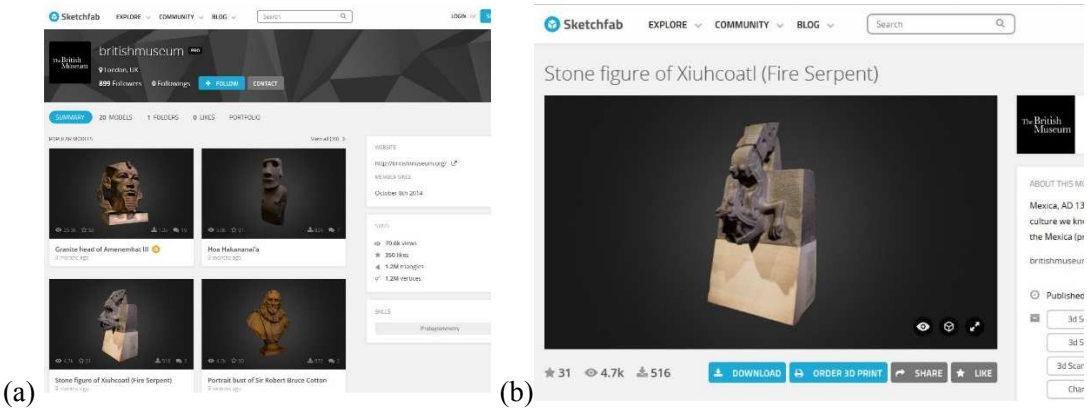
themselves even before setting foot inside a museum. Research on museum websites yielded two distinct methods utilised by museums to present their digitised collections online: websites and AR apps.

2.2.1. 3D cultural heritage objects on museum websites

When museums have an online presence, visitors can quickly access information and collections online. The National History Museum in London provides an example of the rapid growth of online museum audiences. Within ten years from the launch of the National History Museum's website, the number of visitors to its website tripled the number of visitors to its physical museum (Barry 2006). With so many website visitors, museums started to offer online access to their collections, first as images, then as videos, and more recently, as 3D models. A survey found that a majority of people visit a museum's website before the physical museum visit, especially when a museum has a large collection, frequently changes its collections or exhibits, or is new to visitors (Marty 2007). After surveying visitors to several different types of museums' websites, Marty (2008) learned that visitors found museum websites important and complementary to a physical museum visit. Furthermore, his results suggested that visitors have different needs and expectations when visiting a physical museum compared to when they visit its website. He recommended that websites offer experiences that visitors might be unable to have in a physical museum.

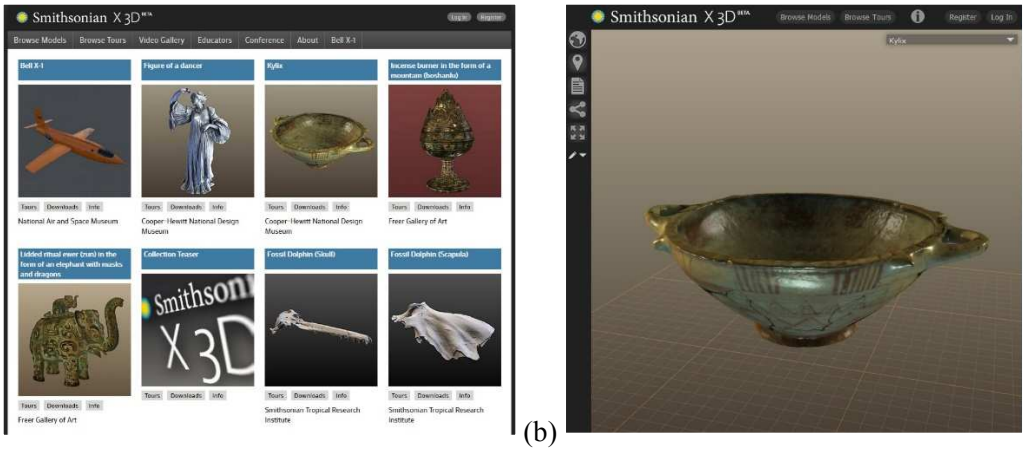
By providing interactive 3D artefacts online, museums have addressed visitor requirements for unique experiences. Many museums contain objects that are historical or irreplaceable, and these are displayed in protective cases. This glass barrier prevents visitors from rotating artefacts to see different angles, as well as moving artefacts around to identify how objects may have been used. These are objects that visitors can potentially gain more knowledge about through interaction and closer inspection. Latham (2012) viewed cultural museum artefacts as representations of the past and 'potentially informative'. Museums like the British Museum (2015a), the Smithsonian Institution (2015), and the Petrie Museum of Egyptian Archaeology (2015a) have interactive 3D models of skulls, statues, fossils, and practical and ornamental objects available on their own websites or through

dedicated 3D publishing platforms like Sketchfab (2013). Examples from these websites are shown in Figures 1-3.



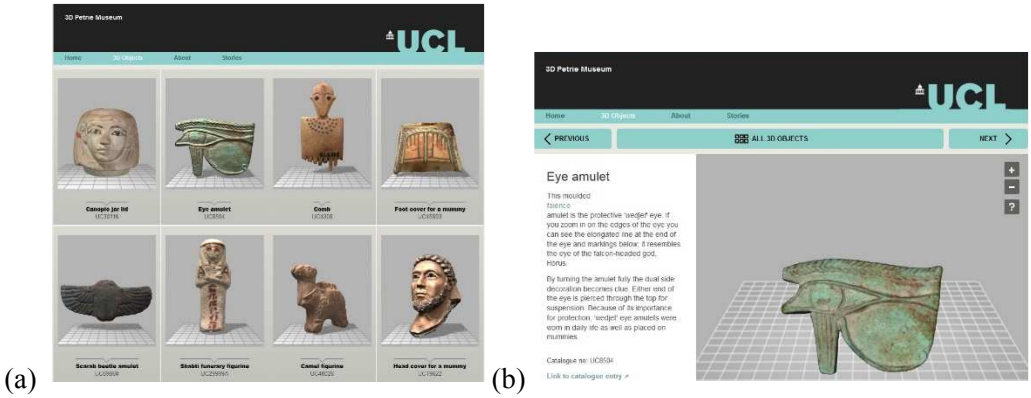
(a) (b)

Figure 1. 3D models from the British Museum: (a) homepage; (b) selection of the Stone figure of Xiuhcoatl (Fire Serpent) 3D model



(a) (b)

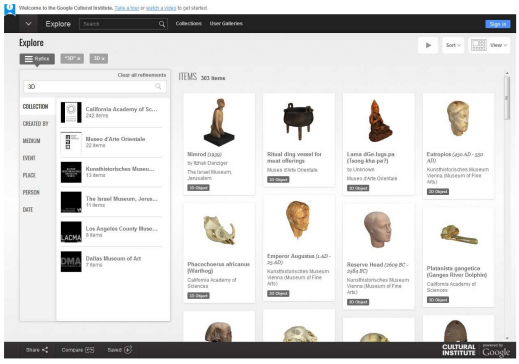
Figure 2. 3D models from the Smithsonian Institution: (a) homepage; (b) selection of the Kylix 3D model



(a) (b)

Figure 3. 3D models from the Petrie Museum of Egyptian Archaeology: (a) homepage; (b) selection of the Eye amulet 3D model

There are also websites with a digital library of collections from many cultural institutions. Specifically, Google Cultural Institute (2015) is a website that showcases digital collections and exhibits from museums all over the world, including 3D models of artefacts (see Figure 4).

(a) 

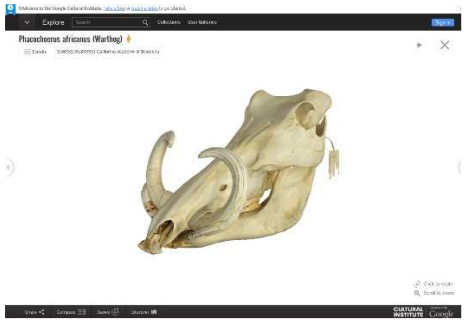
(b) 

Figure 4. 3D models from the Google Cultural Institute: (a) homepage; (b) selection of the Phacochoerus africanus (Warthog) 3D model

Europeana (2015) Foundation created a website dedicated to bringing together cultural heritage from all over Europe in the form of images, audio, video, and 3D models. The European Virtual Museum, created by the Form Multimedia System for a European Museum (F-Mu.S.Eu.M) (FMuseum 2015), also contains objects from several European museums and offers related content through 'linked thematic routes'. The Ashmolean Museum of Art and Archaeology (2015) developed a downloadable book for users to interact with 3D models from their collections. 3DMuseum.org (2015), while not associated with a museum, was established from the efforts of two universities, the University of Oregon and the University of California, Davis to 'provide the pure enjoyment of looking at natural objects, mostly animal skeletons, in 3D'. Currently, interaction with 3D artefacts on museum websites usually consists of zooming in and out, rotating, and repositioning, all of which enables closer inspection of artefacts by the user. Together, these controls can even give users an understanding of how to handle or use the artefact, contributing another layer to their knowledge of the artefact.

2.2.2. AR apps

In addition to museums offering 3D artefacts on websites, some have also created AR apps for mobile devices such as tablets or smartphones. Similar to interacting with 3D models on websites, AR equally allows for personalised artefact experiences. AR is a technology that allows digital objects to be superimposed onto the physical, real-world environment as a method of enhancing a view, and usually requires the use of mobile devices such as tablets rather than PCs. Traditional PCs do not share some of the functionalities of mobile devices, specifically for providing the backdrop of the real-world that is needed to superimpose the digital object. In contrast to viewing 3D models on websites, the Internet is initially required to download an AR app. Once the user has downloaded an app to their mobile device, it can be accessed at any time and usually does not need an Internet connection to operate. In museums, AR is most commonly used in mobile guides (Chang et al. 2014; Chen, Chang, and Huang 2014; Tillon, Marchal, and Houlier 2011; Damala et al. 2008). Moreover, integrating AR into museum display systems supports learning (Lee 2012), specifically to assist with contextualising or visualising artefacts and sites (Damala, Marchal, and Houlier 2007). While these systems enhanced many visitors' museum experiences, they also had some disadvantages. Some felt that the technology was distracting, which prevented visitors from focusing on the physical museum object or the real environment, and there were some difficulties when focusing on the museum object while controlling the system with both hands (Tillon, Marchal, and Houlier 2011; Damala et al. 2008; Miyashita et al. 2008). The tablet was also deemed cumbersome if used as a guide (Chang et al. 2014). Some visitors who were unfamiliar with AR technology were startled when a 3D model suddenly appeared or found the digital object 'more beautiful' than the physical object (Miyashita et al. 2008).

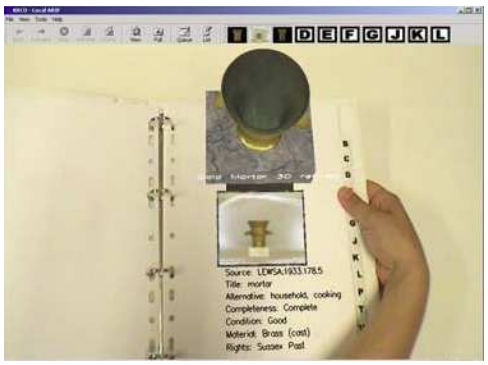
On the other hand, integrating AR into a museum experience also has some advantages. If museums allow visitors to download AR apps onto their own mobile devices, the familiarity with their own devices could negate any problems with visitors getting accustomed to the technology or finding the novelty of the technology distracting. Museums benefit from allowing visitors to download AR

apps on their own personal devices since they do not have to acquire the devices or maintain them (Bruns et al. 2007). Another advantage of downloading AR apps is that it allows visitors to potentially engage with artefacts both inside and away from the museum. While Brown (2007) declared that AR is best used for objects that are 'difficult or impossible to access', most museum artefacts can only be seen passively and can therefore benefit from AR. AR apps for mobile devices provide a way to uniquely interact with a museum and its collections even through the user may be nowhere near a museum. Presently, the Petrie Museum of Egyptian Archaeology offers apps for touring the Nile River and examining 3D artefacts (Petrie 2015b). The Museum of London created an AR app that allows old and new streets of London to be discovered as the user walks around the city (London 2015). The British Museum's available apps enable users to explore the Parthenon Gallery through AR games or browse collections and explore past cultures from their mobile phones and tablets (British Museum 2015b, 2015c). While these apps were created for users to enjoy outside of a museum, they suggest that many museums may have not fully considered AR as a method for users to simply view and interact with digital artefacts on their personal devices, perhaps due to the availability of interactive 3D models on their websites. Additionally, since AR technology necessitates the use of mobile devices, their cost may be prohibitive for some users to consider AR, especially when they can access the same type of information on websites.

2.2.2.1. Methods of integrating AR for viewing 3D museum artefacts

That being said, research focusing solely on incorporating 3D artefacts in AR museum applications has been conducted in the past. As with 3D artefacts on websites, 3D artefacts viewed using AR methods are also interactive, but AR has the distinction of being superimposed onto real, physical objects. Unlike viewing 3D models on websites, the AR systems in the following studies allow the user to place a tangible target, which has the 3D artefact virtually linked to it, anywhere in the physical world and the digital artefact will appear alongside physical objects. This method also gives users more control over their interaction with the artefact since they can pick up the target with their hand to move and rotate it.

The 3D modelling and AR visualisation processes of museum artefacts were discussed by White et al. (2003), but they focused on viewing the physical artefact together with the digital model. Later, White et al. (2004) developed ARCO (Augmented Representation of Cultural Objects), an architecture that provided museums with methods to digitise, display, and manage digital artefacts in virtual environments, including both websites and AR applications. Liarokapis and White (2005) proposed a method for museums to create 3D models using photographs and superimposed real and virtual objects to form one whole object. Visitors could then view and interact with complete artefacts that are inaccessible or damaged in real life. Interaction with restored historical artefacts was also the aim of the work of Saggio and Borra (2011), but their interaction with the AR artefact required extra hardware, for example, a data glove that measured hand movements. Liarokapis (2007) suggested an AR implementation for museums where users could view and interact with only digital artefacts. The application, utilised in ARCO, enabled groups of visitors to view the virtual galleries and talk about the artefacts with each other. The ARCO system was evaluated by Sylaiou et al. (2008), but they focused on its usability rather than the museum visitors' responses to the digital artefacts. Figure 5 provides some examples of interactions with 3D objects using ARCO.

(a) 

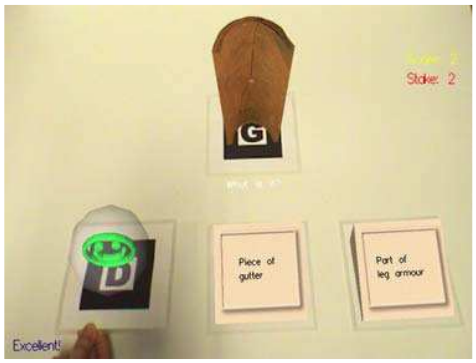
(b) 

Figure 5. Examples of the ARCO approach from Sylaiou et al. (2008): (a) *Magic Book*; (b) interactive quiz

Another approach for creating AR environments, called Augmented Reality Environment Modelling (AREM), was developed by Wojciechowski (2012) and tested in ARCO. His method similarly enabled museums to display 3D cultural objects in interactive AR environments. Figure 6 shows a user interacting with a

virtual object through a quiz by choosing correct answers displayed on different physical markers.

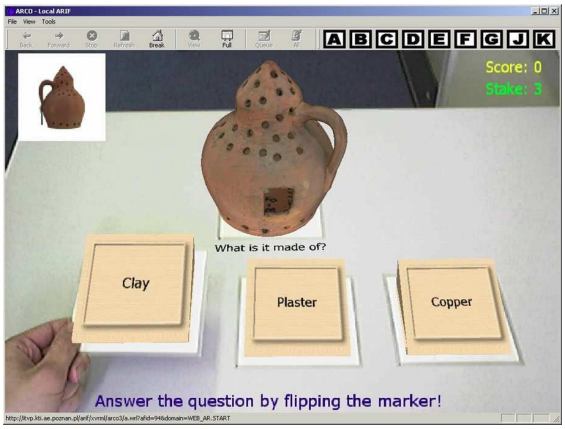


Figure 6. Example of the AREM approach from Wojciechowski (2012)

These studies demonstrate that museums have taken advantage of the interactive capabilities of 3D models of artefacts by making them available on websites and AR implementations. However, in all the above cases, solely viewing digital artefacts without a game context or outside a physical museum were not considered. Unfortunately, even though haptics technology presents unique museum opportunities, it is not as readily accessible as personal devices. Therefore, users do not have much opportunity to virtually 'touch' artefacts when they are outside a museum. This study will concentrate on modalities that are more ubiquitous in people's everyday lives, such as websites accessed through PCs and apps on mobile devices.

2.3. Comparing digital artefacts with physical artefacts

Digital artefacts are clearly different from the physical artefacts from which they were modelled. Also known as 'surrogates' (Taylor 2009; Frost 2002), digital copies exist virtually, made of bytes instead of materials such as metal, wood, clay, bone, or ceramic. Visitors travel to museums in order to view and be in the presence of artefacts made from these tangible materials. Pearce (1994b) claimed that the value placed on real artefacts is a museum's 'greatest strength'. Despite this, Cameron (2007) stated that the digital artefact can also evoke emotions since it does not have a

separate message or materiality from the physical object. The digital artefact is associated with a museum through its placement on the website, giving it 'authority' and 'integrity' (Cameron 2007). When museums choose to create 3D models of their artefacts, they are usually forthright about the digital artefacts being copies of physical artefacts in museums. The process of digitising artefacts first requires a deliberate selection of physical artefacts to digitise, an 'active process of value and meaning' (Cameron 2007). This suggests that digital artefacts are significant to the museums, but others might not necessarily view them the same way. Nevertheless, removing the digital artefact from the physical museum can 'shift the balance of power and authority associated with it' to a global audience (Hogsden and Poulter 2012a) because it can connect viewers from all over the world, many of whom may have different interpretations that can now be exchanged online.

In his seminal essay 'The Work of Art in the Age of Mechanical Reproduction', Benjamin (1939) reflected on the effects of reproducing a work of art, which included how the copies 'substitute mass existence for a unique experience'. Malpas (2007) applied Benjamin's claims to cultural heritage, stating that new media has to 'maintain the integrity of heritage artefacts and sites and maintain a sense of the distance and difference between the past and present'. However, a broad audience could still have unique experiences with digital artefacts when the 3D model clearly shows deterioration over time, indicating that they have existed for many decades and created by people in different cultures. The issue here is perhaps when users first see a digital artefact away from a museum and whether they recognise that they are viewing a unique and significant artefact that has a history. When a digital artefact is made available online for anyone to access, it can be viewed at any time, thus enabling viewers to interact with it before seeing the physical artefact in a museum. This interaction mainly involves the viewer (or user in the case of interactive digital artefacts) and the digital artefact, without any assistance from the physical presence or supplementary context of a museum. These circumstances can affect viewers' responses to and understanding of an artefact.

2.3.1. Lack of museum context

When digital artefacts are removed from both a physical and virtual museum space, they no longer have many aspects of the physical museum's context that might contribute to a visitor's response. This is different from reconstructing entire museums down to the smallest detail to create online virtual museums (Kotsopoulos et al. 2010), since the museum context is still present, albeit virtually. Physical museum context in this thesis refers to Falk and Dierking's physical context from their Interactive Experience Model. In this model, the physical context includes not only the museum's architecture, but also the placement of galleries, display choices, docents, exhibits and labels, supplementary narration or information in the form of audio and video, and any technologies used to interact with objects in the museum (Falk and Dierking 1992b, 1992c). Falk and Dierking have since included digital and online tools as part of all three contexts of the museum experience: personal, sociocultural, and physical. They highlighted museum websites as sources of information for preparing for a visit and social media as opportunities to co-create a museum experiences (Falk and Dierking 2012). However, they did not focus on the interaction between visitors and digital artefacts either in museums on online. Applying Falk and Dierking's model to the experience of interacting with digital artefacts outside of the museum is beyond the scope of this thesis, but it can provide a definition for the museum's physical context.

Past research has indicated that a museum's environment and display methods have influenced emotional responses to artefacts (Gadsby 2011; Locher, Smith, and Smith 2001) and meaning making (Ciolfi and McLoughlin 2012; Schorch 2012), but Hogsden and Poulter (2012b) determined that museum artefacts viewed online and away from a museum can be engaging and meaningful. Still, there is concern that digitised artefacts removed from their context will lead to their being 'experienced and interpreted in ways that were unintended'. Context here is defined as 'those properties of an object related to its creation and preservation that make the object's origins, composition, and purpose clear' (Beaudoin 2012). Digitising a physical artefact transforms an object made by people using materials such as clay, wood, and stone, into an object consisting of bytes and represented in pixels on a computer

screen. Even if a digital artefact has the same colours, textures, and patterns, the digitisation requires the use of technology, which may separate the viewer from an object's original context, especially if the object was created hundreds of years ago before this type of technology was available. This may be an issue for those seeing the artefacts for the first time on a computer since they might just see a beautiful object made using modern technology, and not grasp just how important it was for a culture's way of life. In a museum, an artefact is generally displayed alongside related objects and arranged according to a certain timeframe, which helps to contextualise its meaning.

Based on Beaudoin's definition, it can be said that the physical artefact in a museum has already been removed from its original setting and context; this is analogous to digitising a physical object from a museum and placing it online (Müller 2002). Pine II and Gilmore (2007) clarified that encounters with artefacts that were 'artificially placed within the confines of museums' are still authentic experiences that happen within us, and therefore, one cannot have an inauthentic experience. In contrast to this belief that the authenticity of an experience is not contingent on an authentic context, Beaudoin (2012) argued that context is an important property of an object, especially cultural objects. Without it, artefacts might be misinterpreted. Similarly, Svensson (2008) supported the use of text alongside ethnographic objects in order to adequately contextualise objects. Dudley (2012b, p. 6) disagreed with this, citing an example where additional text provided by the museum might have prevented her emotional response to a museum object she knew nothing about. Here interpretation manifested itself in her emotional response, and that was powerful enough. She stated: 'Textual interpretation in particular can act to dilute, if not remove altogether, the sense of magic and mystery that objects can so often convey.' However, her response to the object, a large, bronze horse placed on a plinth, was not only influenced by its size, but also the fact that it was on a platform and not surrounded by glass or other artefacts. Gurian (1999, p. 180) likewise 'acknowledged the power of some objects to speak directly to the visitor', but for her, the issue still required further analysis. While accessing digitised artefacts online through personal devices may not accurately capture an artefact's size, the technology will enable users to

focus on one artefact at a time, interact with artefacts, and view them from numerous angles.

Both Gurian (1999) and Müller (2002) anticipated that museums will ultimately implement more narrative methods of exhibiting objects instead of focusing on the object. A few years later, Svensson (2008) maintained that text alongside the artefact is required since 'objects can not speak for culture'. This seems to be the case for digitised artefacts as well, with some endorsing collaborative narratives in the form of audio or video to help viewers understand the significance of indigenous heritage objects from both museum professionals' and indigenous people's viewpoints (Vermeylen and Pilcher 2009). Rahaman and Tan (2011) similarly called for more collaborative, narrative methods for interpreting digital cultural heritage, but focused on the end-users' perspectives since meaning-making is a 'dynamic process'. These types of narratives recommended that people contribute their own stories about an artefact through photos, videos, or audio, which others can access while they interact with the digital artefact. Di Benedetto et al. (2014) maintained that when interactive 3D cultural heritage artefacts are made accessible online, they should be linked to related content to explain what they represent and how they were created, but this was in reference to more artistic objects. Still, as Dudley demonstrated, emotion and meaning are possible when based solely on the interaction between the viewer and the artefact's physical properties.

2.3.2. Artefact's physical characteristics

In contrast to those who believed that context is important, Dudley (2010) suggested that it is a museum object's physical properties that 'exclusively' influence the viewer's experience. Likewise, Hooper-Greenhill (2000) stated that 'the power of the meaning given to objects is grounded in their material character'. Dudley (2013) later recognised that the physical characteristics of objects 'remain inadequately explored in the material cultural literature as a factor in the relationships between people and things'. This can apply to digitised museum artefacts, since many of the same elements are captured from the physical artefact. An artefact's shape, size, colour, and materials all contribute to what viewers see when interacting with it.

These properties represent the materiality of an object, and materiality also involves engagement (Dudley 2010). Maroević (1999) maintained that a cultural heritage object 'carries its symbolic and other semantic values within its structure'. Malpas (2007) agreed that 'culture is always tied to its materiality and inseparable from it'. This is reflected in the work of Brown (2007), who proposed that the physical artefact's properties, along with their cultural values, are transferred over to the digitised artefact. In this sense, context is inseparable from the artefact. Comparably, Vecco (2010, p. 324) defined cultural heritage as objects that provoke 'values that led the society in question to consider it as heritage'. Materiality of digital objects also refers to the space required to store them, and if they are interactive, they also have a physical presence (Newell 2012). These definitions suggest that an object's materiality establishes an interaction between the object and a viewer, and from this interaction, connections between the two can be formed. Speaking in general about digital objects like software, Leonardi (2010) defined materiality as 'representing the practical instantiation and the significance of an artifact'. He also maintained that digital objects can mean different things to different people, owing to what features are significant to the viewer. His concept can also be applied to digitised museum artefacts: the practical instantiation is the digitised museum artefact and its significance depends upon the viewer.

Since digital artefacts provide museums with another method of presenting and organising information, technology has prompted museums to not only change their practices, but also redefine themselves. Parry (2007) examined the history of museums adapting to technology, including how some museums initially 'underestimated the resources and skills needed to go digital'; as a result, they were slow to adjust, allocate money, and invest time. When museums utilised technology to digitise their catalogue through standardised methods, it went against traditional methods of curating because objects were separated from their traditional museum contexts and information, which curators work hard to bring together. Parry (2007) also discussed how technology, when used to convey museum content, could have different personal meanings to users. This contributes to how content and the museum are experienced by a visitor; if some visitors frequently use certain technology and are familiar with it, then they might have different experiences with

the same content than those who are unaware of that technology or rarely use it. Similarly, Copeland (2006) reviewed how museums digitally transform their materials so diverse groups of visitors can access them using different technologies. She provided the examples of The Minneapolis Institute of Arts in the US, which provided a live-feed to audiences of a behind-the-scenes museum tour online, and the Exploratorium in San Francisco, California, which combined handheld devices and the Internet to engage users with exhibits and continue visits with other visitors in shared museum spaces. Although the same exhibits were seen, and the same technologies were used for the digital experience, audiences had different experiences because of their diverse backgrounds and where and how they accessed museum material. This is particularly important for learning in museums and reaching a wider audience, as people have different methods of learning, and digital technologies provide different options.

2.3.3. Advantages of digital artefacts

Thanks to innovative digitising methods that can capture every feature of complex objects, interaction with digital artefacts provides an engaging way to see details that normally would be inaccessible in a museum. Due to the fact that the physical artefact remains in a museum and cannot be moved by visitors, digital artefacts offer a method of interaction that physical artefacts are unable to provide due to their fragility or value. Users can interact with a digital artefact through technologies and 'explore its characteristics and history' through controls such as zooming, rotating, and moving (Müller 2002). Users not only can control what part of the artefact they want to see, but since digital artefacts are available online, they can also decide where and when they want to access digital collections. As users are generally already online when they access digital artefacts on their computers, they have the option to use search engines to learn more about an artefact's history, visit museum websites for similar collections, or contact curators for more information. Giving users the option to access digital artefacts on a website and AR app can offer them different types of engagement through the interactive online media that they seek, as evaluations conducted at museums suggested (Barry 2006). By enabling access to digital artefacts through websites and AR apps, additional learning opportunities for

users are created. This ability to examine artefacts contributes to the user's learning of the artefact's materials and history (Newell 2012).

Digital artefacts can extend a museum's audience globally. With online access to digital artefacts, anyone can access the museum at any time of the day from anywhere in the world. This can affect how people exchange information; researchers in different countries can readily access artefacts and potentially exchange historical data with museums through the Internet. Museums may also become more approachable to those who feel intimidated by museums and their vast collections. For those who live locally to a museum, the weather, admission fees, or travelling costs might be factors in deciding not to visit a museum in person (Falk and Dierking 1992a); viewing an artefact digitally from home might be more convenient for them. Although viewing digital artefacts might take place outside of a museum, this experience does not have to be an isolating one. Fritsch (2007) believed that museum websites can encourage more people to communicate their visitor experiences through outlets like blogs and videos, and digital artefacts can be catalysts for sharing museum experiences.

Digital artefacts are also essential not just for broadening a museum's audience globally, but also for preserving artefacts for audiences in the future. Some artefacts are fragile and deteriorate over time; therefore, they might look different now compared to how they will look in the future, just as some artefacts today have appearances that have changed since they were first created. Cameron (2008, p. 176) discussed how digital heritage is important for future audiences as the surrogate provides a 'tangible link with past time, as confirmation of enduring identity in a volatile present'. Through digital artefacts, the viewer is able to see how a physical object has changed over time through its patterns, colour, shape, and texture. This can assist with learning and understanding of an artefact. Future generations can use these digital artefacts when creating their own online contributions (Cameron 2008).

Visitors to museum websites 'access, view, and engage with' objects online (Gillard 2002). Websites create a continuous user experience where visitors always have access to museum collections; this is also referred to as a 'virtuous circle' (Barry

2006). The ability to interact with 3D artefacts can lead not only to continuous learning from the website to the museum, but also a renewed interest in a museum if users become interested in a digital artefact and aspire to see it in person. Moreover, interactivity with museum collections though digital means has been shown to motivate users to revisit museums (Mikalef et al. 2012).

Digital artefacts can also lead to repatriation, returning artefacts to their original sources. The digital or physical artefact can be 'rediscovered' by and reconnected to the original community (Newell 2012; Brown 2007), give communities 'ownership and authorship over the digital replica' (Hess et al. 2011), and lead to building digital networks for exchanging information and interpretations between online collaborators (Hogsden and Poulter 2012a).

2.3.4. Concerns about interacting with digital artefacts

While there are many benefits for interacting with digital artefacts, there also exist some concerns about interacting with them through a computer or mobile device. Orr (2004) suggested that museum websites prohibit the user's ability to create meaningful experiences with online collections due to the 'barrier of screen and machine'. Even though physical artefacts are themselves behind glass barriers, many people visit museums to be in the presence of original artefacts and see them in person. Other unique factors of a physical museum visit include the opportunity to visit historic buildings that house the artefacts and the social aspect of being among other visitors who share the same interests; these all contribute to a meaningful experience. Without these factors, viewing the same artefact on a computer screen might provide a completely different experience. Cummings and Lewandowska (2001) refuted concerns that the computer screen cannot take the place of actual contact with museum artefacts since museum artefacts are usually displayed behind glass. However, they were speaking about the act of viewing the artefact itself rather than the entire museum experience, which entails other factors such as the physical museum environment, other visitors, and artefact display methods. While visitors may not be able to physically interact with original museum artefacts and they can digitally interact with artefacts online, nothing can replicate the experience of

actually being in the presence of an original, physical artefact, seeing curated displays in a museum, and having access to nearby knowledgeable docents.

Another issue is that virtual museums, along with their digital artefacts, might decrease the number of visitors to physical museums because of museums' increased online presence in response to raising their profiles and pressure to expand their audiences amidst lower budgets (Hume and Mills 2011). Hume and Mills' (2011) case study found a decrease in physical museum visitors due to online visits for some museums, but it depended on what museums offered online. When museums used online methods to promote themselves to visitors, offer virtual visits to those who are unable to visit the museum in person, and provide information for in person and online visitors, both online and physical museum visitors were engaged. Accordingly, museums saw increases in both types of visitors.

A third concern relates to the devices used to access digital artefacts. Past HCI research has investigated the usability of interfaces and user's emotional responses to a system's design. Research has shown that interacting with mobile devices themselves can bring out various emotions, depending on the device's usability (Sandberg 2011; Mahlke, Minge, and Thüring 2006). If users are to interact with digital artefacts using personal devices like smartphones, there is a concern that the device might influence their emotional connection to the artefact. Therefore, it is necessary to explore whether users experience emotion and meaning in response to the digital artefact itself.

In this section, it is clear that interaction with digital artefacts has many benefits. Additionally, studies have shown that the physical attributes of artefacts should be sufficient for enabling an interaction between the viewer and artefact, even without many of the museum's physical contexts. However, there are still concerns about whether interacting with online digital artefacts can lead to emotional connections and the construction of meaning. Now that online access enables viewers to interact with artefacts before visiting the physical artefact in a museum, there remains a need for a clearer understanding of these types of responses to digital artefacts on personal devices outside the museum.

2.4. Emotional responses to digital and physical museum artefacts

2.4.1. Definition of emotion and their importance in museums

Responses to museum artefacts include cognitive and affective components, and the affective (hereafter referred to as emotional for consistency) response is 'an essential part of understanding museum objects' (Taylor 2009). Furthermore, consciously experiencing emotion involves 'past feelings (memories), hypothetical feelings (imaginings), or feelings that are occurring in the moment (on-line experiences)' (Barrett et al. 2007). Emotion is 'the single quality that matters most' when trying to understand artefacts due to emotion being processed faster than cognition in the brain (Taylor 2009; Barry 1997; Arnheim 1974). Experiencing memories in response to museum collections is an indicator of memorable experiences that have a 'lasting impact' on visitors' (McManus 1993). Heritage sites in particular are seen as places where visitors feel emotions as these sites are linked to 'identity, belonging and sense of place', and they also reveal how visitors respond to 'curatorial messages' (Smith 2014). When referring to museum collections of photography, Edwards (2010) defined emotion as 'an intense, individual and subjective embodied, sensory experience related to a state of mind, in relation to contexts, determined through practices of non-verbal communication'. This is similar to Harris and Sørensen's (2010) definition of emotion, 'the act of being moved, which is always tied to specific situations and the perception of particular bodily states'. Harris and Sørensen were specifically referring to material culture in their definition, and they implied 'no separation between body and mind'. Material culture can be thought of as 'selective lumps of the physical world to which cultural value has been ascribed' and includes natural history objects (Pearce 1994a). These definitions help explain why emotion is an important part of connecting with museum artefacts and how it is related to context and specific situations.

In archaeology, material culture can also assist with understanding the types of emotions people in the past experienced and why they were significant (González-Ruibal 2012; Tarlow 2012; Harris and Sørensen 2010; Tarlow 2000). Non-archaeologists can similarly empathise with people of the past through artefacts that

still exist, which are made accessible by museums and similar institutions. However, the methods for presenting digital artefacts may not offer much space for displaying detailed histories alongside them, or viewers might bypass any descriptions or supplementary narrations and immediately interact with the digital artefact. In these cases, viewers would have to rely mainly on an object's characteristics to form their responses. Dudley (2010) explained that the physical properties of an object prompt cognitive and emotional connections; this interaction forms the object's materiality. Moreover, the significance and meanings of ethnographic and cultural artefacts are reflected through their craftsmanship and beauty; these represent cultural values (Brown 2007). As a result, the properties that trigger emotional responses to the physical artefacts remain in the digitised copies, and the digital artefact's 'similarity to the real thing allows [the digital artefact's] creators to invoke emotions' (Cameron 2007).

Museums have been described as experts at 'eliciting emotion', among other capabilities, which they should share with the public (Weil 1997). This expertise aligns with the needs of older and younger adults. Older people often visit museums to reminisce about the past (Sheng and Chen 2012; Aldridge and Dutton 2009), and memories often lead to the experiencing of emotions (Wood and Conway 2006). Young adults also want to make emotional connections with museum artefacts (Kelly and Groundwater-Smith 2009). Visitors' emotions are in response to a variety of factors, including the contents of a museum's collection and an object's properties. Emotions are also prompted by the physical presence of museums due to their imposing architecture, grand entrances and ceilings, lighting, and 'settings for rituals' such as behaving with decorum in spaces designated for learning and reflection (Duncan 1995).

Activities offered in museums as part of community engagement and education also provide opportunities for families, friends, and individuals to experience emotions. In fact, emotion is 'key to [community engagement's] perceived social impact' not only by visitors, but also the facilitators who lead the community engagement programmes (Munro 2014). For instance, Glasgow Museums offered a programme where facilitators encouraged recent immigrants to engage and interact amongst

themselves on many topics. This affected the facilitators' and immigrants' self-esteem, self-confidence, health, and well-being, as facilitators had to be prepared to understand and respond to immigrants' conversations, and immigrants had a safe and supportive place to go to discuss their feelings (Munro 2014). Group activities for friends and families also offered positive impacts on emotional responses in museums. Camarero-Izquierdo (2009) examined several aspects of group activities that influence the degree of emotions experienced in cultural activities. Her findings identified that new technologies helped to increase emotions experienced, more positive emotions were experienced the larger the group, and participation was important in experiencing stronger emotions.

There are also new technologies that assist with experiencing emotion in museums or understanding emotional responses. Roccetti et. al. (2013) created a mobile app that supports 'cultural emotional browsing' in a museum by recognising the users' moods through the shape of their mouths and offering suggestions on what content to visit. If a user is happy, then more positive suggestions are offered and all negative content is hidden. Social media sites such as Twitter are often used to post opinions, reviews, and comments on different events, and this includes visits to museums. Since this can have a direct effect on museum attendance and support, social media is being considered as part of emotional responses to museums. There has been an increase in research related to understanding emotions and sentiments in texts, including the creation of a classification method for sentiment in tweets (Balahur 2013) and a framework for sentiment analysis using emotion signals such as emoticons (facial expressions) and product ratings (Hu et. al. 2013).

When emotion is experienced during a museum visit, both in-person and online, it impacts both visitors and museums. Emotion has been linked to trust, resulting in meaningful and frequent visits, and monetary and voluntary contributions (Suchy 2006). In addition, Witcomb (2007) emphasised that having digital technologies in museums can increase the 'affective possibilities of objects'. Although she was referring to digital implementations within a museum, the integration of interactive technologies with digital artefacts can similarly be considered supplemental interaction with the artefacts, and therefore, these technologies can enhance

opportunities for emotional connections. The importance of emotions in museums is reflected in previous research conducted on emotional responses to works of art, cultural artefacts, and exhibits inside a museum (Lopatovska et al. 2015; Damala et al. 2013; Dudley 2012b; Suchy 2006; Silvia 2005; Csikszentmihalyi and Robinson 1990; Berlyne 1971). While the differences between works of art and cultural heritage artefacts are beyond the scope of this thesis, both types of objects are exhibited in museums, and viewing them can lead to emotional responses from viewers. Copies of artworks exist in many different formats, and there have been studies comparing emotional responses to both the physical and digitised museum artworks. This is most relevant to this thesis, as responses to physical and digitised cultural heritage artefacts will be compared.

2.4.2. Comparing emotional responses to physical and digitised museum collections

Focusing on non-3D museum objects, previous research compared visitors' emotional responses to museum collections in the form of artworks, which were presented in different formats including the physical artwork and digital copies. Most of these studies used separate groups of participants for each format, so responses to the same artworks in every format from the same participant were not compared.

A study by Locher, Smith, and Smith (2001) focused on responses to nine original oil paintings at the New York Metropolitan Museum of Art and their slide-projected and digital images. Evaluating the original painting were 20 art-trained and 20 non-trained visitors to the museum. Another 20 participants who attended workshops were selected for the art-trained group for the slide images, and 20 more were chosen for the art-trained group for the computer images. Undergraduate volunteers formed the untrained groups for each of the slide and computer images. The participants viewed the original painting in the museum gallery, the computer images in an office setting, and the slide images in a small auditorium. Their task was to rate each artwork on a scale of 1-9 based on 16 adjective pairs such as simple-complex, usual-surprising, common-rare, unpleasant-pleasant, and uninteresting-interesting. The

findings show that the original artwork was rated more interesting and more pleasant than the slide or computer copies, as well as more surprising and rare. The slide and computer reproductions often did not differ. The responses regarding the sameness of the artworks for the trained and non-trained were similar. They also concluded that viewers took into account the limitations of the copies and only focused on the art itself.

In an investigation conducted by Taylor (2001), 20 oil paintings at the Toledo Museum of Art in Ohio, along with their reproductions in four other formats, including books, computer images, black-and-white glossy photographs, and colour slides, were presented to 86 participants for their feedback on the artworks' expressional content. Participants saw the original painting displayed in the museum and were asked not to read any caption information. They viewed the copies in the museum's registrar's office and a classroom where no caption information was provided. Each participant saw all 20 paintings only once, and each participant was randomly shown a painting in one of the five formats and in a different order from other participants. After each painting, they were asked to identify, not interpret, the emotions and feelings in each painting from a controlled list of 136 terms shown in groups of 25. Taylor concluded that there was a significant difference in identifying emotions in the original artworks and the copies due to physical factors of the original. Seeing the actual colour, size, and scale made it easier to detect emotions in the originals. In addition, the format that replicated the feeling of viewing the original artwork was the colour slides, which were projected onto a surface that was much larger than any of the other formats. Although the study concentrated on the differences among these formats, Taylor also found that the museum and its physical context influenced participants' responses to the original oil paintings.

While not focused on emotional responses to the artwork, Quiroga, Dudley, and Binnie (2011) determined how the format of an artwork affected viewers' experiences. Contrasting an original oil painting at Tate Britain with one shown digitally on a monitor in a lab, they observed the eye movements of 14 participants; six looked at the original oil painting, titled *Ophelia*, in the gallery while eight looked at the digital copy in a lab. Each participant was shown just one of the

formats; only the first 60 seconds were taken into consideration. For the digital image, most of the participants focused on the face of the main character, while in the original format, they looked at the sections around the main character. This was attributed to the fact that in the original, viewers could see brush strokes and texture, which encouraged seeing the details of the whole image. The digital format had other constraints besides its lab setting since participants were given a set amount of time and a distance from which to view the image.

2.4.3. Emotional responses to digital museum artefacts

Interacting with digital artefacts on technology such as mobile devices and computers is becoming more common, as discussed in section 2.2. This can result in a viewer experiencing the digital artefact before seeing the real, physical artefact in a museum. Frost (2002) acknowledged that the digital artefacts might result in a different viewing experience from the physical artefacts due to scale and colour differences. Owing to more advanced methods of digitising artefacts, particularly when creating 3D models, many of the digital and physical objects' properties will look the same. While that does not necessarily mean that viewers' responses to both will be similar, each modality should enable emotional connections between the viewer and the digital artefact.

Some studies explored participant reactions to digitised objects, particularly when a user's first encounter with an artefact is digital. Hogsden and Poulter (2012a) created a digital model of an indigenous Australian artefact from the British Museum and then connected curators and staff from the museum with students, specialists, and museum staff in Australia and Holland through a website where the digital artefact could be accessed. Information and narratives related to the artefact were uploaded to the website by the curators and specialists, ensuring that diverse views were contributed. Hogsden and Poulter were interested in Australian students' responses to the digital artefact that originated in Australia and found that the digital artefact was a 'catalyst for engagement'. These university students in Australia who interacted with the digital museum artefact on a website expressed emotions through their comments and also engaged meaningfully with the artefact. Although their

study only focused on one digital artefact, it established the possibility for emotional connections and the emergence of meaning after first viewing an artefact online.

In the E-Curator project, heritage objects from the University College London's Museums and Collections (UCL) were digitised using a 3D colour laser scanning system (Hess et al. 2011). The researchers' goal was to develop scanning protocols for enabling web access to digitised museum artefacts. The researchers held workshops at UCL and two other museums to observe interactions with the physical artefacts. They found that users, including cultural heritage specialists, curators, and technicians, requested to see the details of artefacts, which were later incorporated into the E-Curator system using the zooming and rotating features. In addition, they conducted case studies that utilised their system. The first case study observed changes to the original artefact over time through comparison with the digital artefact and the second enabled 'digital repatriation'. Overall, they concluded that 3D models used alongside the physical artefact could enable comparisons for a complementary experience. The 3D models used were made available on a website and allowed for the examination of artefacts, but further research to evaluate the responses to seeing the 3D models before the physical artefacts was not carried out.

As a curator at the British Museum, Newell (2012) investigated the affective change of historical artefacts after they had been digitised. She recognised that the real objects had more emotional impact on viewers compared to the digital copies and suggested that technologies are better employed when they complement the real object experience through digital media. Examples of digital media that she suggested may enhance the object are storytelling, songs, and video; these can foster a connection to objects and provide a better understanding of the 'object's cultural contexts'. Even though the addition of digital media is valuable, this is another instance where emotional responses to the artefact might be influenced by context.

This section demonstrates that further research is needed to understand emotional responses to 3D artefacts viewed: on personal devices outside of a museum; before seeing the physical artefact; and from the perspective of age groups with contrasting technology skills, such as older and younger adults.

2.5. Meaning and interactions with digital and physical museum artefacts

2.5.1. Meaning and viewer-artefact interaction

Compared to Beaudoin (2012), Rahaman and Tan (2011), Vermeylen and Pilcher (2009), and Svensson (2008) in section 2.3.1, who argued that context is necessary for understanding artefacts, other researchers considered the interaction between the artefact and the viewer sufficient for the construction of meaning. Generally, museum visitors interact with exhibits to construct personal meaning (Rounds 1999). Pearce (1994b) determined that the meaning of a museum object depends upon the interaction between a viewer and an object. Weil (1997) agreed that a museum artefact does not have one inherent meaning. It is the visitor who interprets the object and applies meaning to it through personal connections made through memories, culture, and beliefs. Cummings and Lewandowska (2001) reinforced this belief, clarifying that the 'financial, emotional, psychological, or cultural' values of objects are not properties of objects themselves, but resulting from the encounter between people and objects. Tilley (1994) similarly specified that material culture objects can have many and 'sometimes contradictory' meanings. Hooper-Greenhill (2000) agreed that objects can have several interpretations, including ones that may be contradictory. She explained that for viewers, objects are a 'target for feelings or actions' and 'enable reflection', and meaning is based not only on one's background and experience, but also on how the viewer relates the past to the present.

This process is similar to how Gosden and Marshall (1999) viewed archaeology objects, which accumulate meaning from their links to people and events. These objects have biographies that are constantly changing depending on people's interactions with them. Latham (2008) referred to Buckland's definition of a document to propose that museum objects are experienced through the relationship between the viewer, object, and meaning. Buckland described documents as being objects that carry meaning (Buckland 1997), and Latham connected it to the semiotics of museum objects. Using Buckland's concepts, she explained that the interaction between a person and a museum object results in meaning. Therefore, increasing access to objects through digital means does not change the way viewers

make sense of or apply meaning to objects. Latham later connected Buckland's information concepts to museum objects and museum visitors' experiences using Buckland's idea that an object connects people to information that would otherwise be lost without its physical presence (Latham 2012; Buckland 1991). More recently, Morgan (2012) defined meaning as 'a complex process of interaction in which people, objects, environments, histories, words, and ideas take part'. Dudley (2013) advocated that first encountering a museum object, without any interpretive materials, can result in forming 'powerful responsive ideas and feelings – even if mistaken or problematic'. These findings suggest that meaning can be given to digital artefacts that are first experienced outside a museum.

There are several theories that explain how visitors interpret objects in museums. In the hermeneutic theory, 'understanding is reached through the process of interpretation' (Hooper-Greenhill 2000). Hooper-Greenhill (1999b) referred to this approach when explaining that meaning is based on prior knowledge and cultural background, and 'interpretation aims to uncover the meaning of a work through a dialogic relationship between the detail and the whole' (Hooper-Greenhill 2000). Similarly, Hein (1998) proposed that museums take a constructivist approach and make their collections accessible for all types of visitors, allowing any visitor to interpret artefacts using previous knowledge and experience; this process is how visitors construct meaning as well as learn (Fritsch 2007). Wood and Latham (2009) utilised phenomenology, the study of subjective experiences and an underused method in museum research, to explain the connection between a viewer and an object. They believed that objects do not have an inherent meaning until viewers assign meaning to them based on objects' contexts within the museum. Since visitors each have their own backgrounds, the meanings of the objects will be different for each person.

2.5.2. Meaning and artefacts viewed outside of the museum

The researchers mentioned in the previous section, Hooper-Greenhill, Hein, and Wood & Latham, all recognised the museum's influence on visitors' interpretations through the museum's exhibition methods. Nevertheless, previous research showed

that when artefacts are removed from a museum and its typically 'reverential environment' (Hooper-Greenhill 1999a), they can still evoke emotions and memories from people in hospitals and retirement homes (Smiraglia 2015; Chatterjee and Noble 2009; Chatterjee, Vreeland, and Noble 2009). Additionally, it was found that university students gave meaning to archaeological monuments they regularly see while outside a museum. Students used mobile devices to share messages whenever they encountered a monument, and this showed that they were able to 'bring museums into the everyday life' (Arvanitis 2010). When extending the museum experience beyond the typical visit, Casey (2003) claimed that 'meaning is no longer intrinsically tied to the object, but instead created in the interaction between the viewer, the message, and the museum'.

2.5.3. Meaning and digital museum artefacts

When viewing a digitised museum artefact instead of a physical display in a museum, the interaction is still between the artefact and viewer. This indicates that it is possible to construct meaning while interacting with digital artefacts. As stated earlier, Brown (2007) concluded that the properties that give cultural heritage objects their meaning are transferred over to their digital copies. When referring to digitising artefacts, some researchers found that meaning is lost in translation, inferring that it is linked to the museum context. Vermeylen and Pilcher (2009) mentioned how online cultural heritage, without any context or narrative from the museum, could result in access to information, but not an understanding of it. Comparably, Beaudoin (2012) acknowledged that preserving artefacts digitally can lead to its misinterpretation if proper context is excluded. She endorsed including metadata, all information pertaining to the artefact, along with the digital artefact to assist with understanding it, but this implies that meaning is inherently part of an artefact. As such, there is still more insight to be gained on whether interaction with digitised cultural heritage artefacts can lead to meaning.

2.5.4. Link between emotional responses and meaning

Emotional responses have previously been discussed in connection with meaningful experiences. Falk and Dierking (2000) maintained that 'the dominant motivation for humans is meaning-making' and as such, recommended that museums combine emotion with learning into their exhibits. Additionally, emotion was mentioned as one of Soren's (2009) '10 triggers for transformational experiences' in museums. Soren defines transformative museum experiences as those that 'profoundly change visitors' and even 'motivate them to transform the way they think and live'. Cameron and Gatewood (2003) researched how visitors emotionally participate in museums and related it to 'numen-seeking', the need to make emotional connections with the past. Through the use of surveys they found that people wanted to view exhibits that they can empathise with or find meaningful and engaging. They also observed that a visitor's education did not affect numen-seeking and concluded that museums that based their exhibits on numen-seeking will encourage more people to visit and learn more about the topic on their own time. Dudley (2012a) specified that emotions are generated from the unique connection between an object and a subject and mentioned that the object itself can be significant to the viewer, without any knowledge about the artefact. She urged museums to implement creative methods for visitors to engage directly with artefacts. This is supported by the work of Cameron (2007), who discussed how digital historical objects can prompt emotional responses, but emphasised that the technology used to produce and display an object should remain invisible to the user. However, there are situations when it is clear that an artefact is digitised, as in websites and AR apps. When technology is needed to access and interact with artefacts, as in the case of personal and mobile devices, the users may have different skills, which can affect their responses.

2.6. Summary

This literature review has shown that there are still gaps in the knowledge concerning interaction with digital artefacts away from a museum and whether users emotionally connect with them and give them meaning, specifically with cultural heriage artefacts. While 3D artefacts on websites and AR apps are two main methods

museums currently use for sharing their digital cultural heritage artefacts, there are few studies that evaluate their potential for emotional connections and meaning according to age groups that may have different technology skills. Since previous research has shown that the physical museum has some influence on the interaction between the viewer and the artefact, taking the artefact out of the museum and digitising it for use on personal devices could affect these connections. In addition, museum concerns about how digital artefacts affect the physical museum experience need to be addressed.

Chapter 3: Preliminary Study - Understanding the Meaning of Emotional Connections to Physical Cultural Heritage Artefacts

The previous chapter provided a background on two diverse types of museum visitors, older and younger adults, the current state of research surrounding digitised museum artefacts and their comparisons with physical artefacts, and how digitised artefacts can support emotional and meaningful interactions. Specifically, cultural heritage artefacts were the focus of several digitising methods and research. Accordingly, this study focuses on artefacts from a cultural heritage, historical, and ethnographic museum.

Before interactions with digital artefacts can be analysed, a greater understanding of how museum visitors interact with physical cultural heritage artefacts is needed. Dufresne-Tassé and Lefebvre (1994) examined how meaning resulted from museum visitors' interactions with physical museum artefacts to explore the process of learning in museums; emotion was also a part of their framework. Hogsden and Poulter (2012b) investigated whether Australians who had cultural links to an artefact in the British Museum engaged with the digitised version and found them meaningful. However, few researchers have considered how different modalities of interacting with digital artefacts can impact how older and younger audiences make emotional connections and meaning while interacting with artefacts. When audiences access digital artefacts online, they may be away from the physical museum. Museum context is usually helpful for displaying ethnographic and cultural heritage artefacts since they are usually linked to a certain culture, geographic location, and time period. In a museum, these types of artefacts can benefit from the presence of related artefacts or informative displays that group artefacts together to tell a story.

Cultural heritage artefacts encompass historical, ethnographic, and archaeology artefacts as they are objects with recognisable 'aesthetic, historic, scientific, and social values' (Vecco 2010). In addition, 'natural objects' from museums such as a natural history museum can also be treated as material culture (Pearce 1994a). For these reasons, it makes sense to focus on these types of artefacts when designing a

study to understand emotional connections to digitised museum artefacts and the reasons behind them, especially when the digitised versions of these artefacts will be accessed online while outside of a museum.

This chapter presents the results of a qualitative preliminary study conducted at the Powell-Cotton Museum in order to understand what types of physical artefacts emotionally connect with visitors, visitors' emotions felt, and the meanings behind their emotional connections. Reflecting on visitors' responses to artefacts during their visit and afterwards in interviews will establish some of the methods needed for exploring emotional and meaningful interactions with digital artefacts. Specifically, this preliminary study will inform the selection of artefacts that will be digitised for the main study, confirm the self-reporting methods for recording emotional responses, and further clarify the association between emotion and meaning when museum visitors interact with cultural heritage artefacts. This study was reviewed and approved by the Sciences Research Ethics Advisory Group for Human Participants at the University of Kent on 05/07/12 and was conducted between July and August 2012.

3.1. Methodology

3.1.1. Location of study

The Powell-Cotton Museum, located in Birchington, Kent, UK, contains a collection of ethnographic, natural history, and historical objects. These objects were obtained by Major Percy Powell-Cotton during his expeditions to Asia and Africa and inspired him to open a gallery in 1896 to share his discoveries back home in England. During his travels, Major Powell-Cotton hunted and collected animals, many of which were stuffed and displayed in his gallery. His collection grew to over 16,000 objects, which 'illustrate [people's] lives and cultures' (Powell-Cotton 2015a). He kept detailed notes about the objects he collected, and many of the original labels are still displayed alongside the artefacts. Today, the collection at the Powell-Cotton Museum is considered 'internationally significant' (Powell-Cotton 2015b), and the

museum houses the ‘oldest untouched diorama of its type in any museum around the world’ (Powell-Cotton 2015c).

The museum contains eight galleries, and similar types of artefacts are dispersed over one or two different galleries. This structure allows visitors to roam freely and view a wide variety of artefacts. Some of the natural history objects, such as taxidermy animals, are showcased in dioramas that display the animals in their natural habitat (see Figure 7). Many of the other objects are grouped together with a short title and description, some displayed in cases like the weapons and wearable artefacts, and some kept out in the open, like the animal skulls. Due to such large groupings of some of the artefacts, it remains to be seen what types of artefacts stand out to visitors.

Figure 7. Gallery 1 of animal dioramas in the Powell-Cotton Museum (2015d)

Since many of the artefacts remain displayed as they were since the gallery opened, museum personnel are actively seeking ways to engage the modern visitor with its collection. However, they are unsure how to integrate technology like smartphones into a visitor’s experience. Initially, plans to design a mobile application were in discussions with them, but due to the findings of this preliminary study, a new direction was considered. This would allow visitors to access the collections online while outside of the museum using personal devices, but more knowledge is needed comparing visitors’ emotional and meaningful experiences of cultural heritage

artefacts and digital cultural heritage artefacts. First, the preliminary study would investigate visitors' emotional responses to physical artefacts.

3.1.2. Participant selection

Before visitors entered the first gallery, they were greeted and briefly told about the study. All were initially informed of the entire process, with the expected duration of the audio-recorded, one-on-one interview being no more than 30 minutes. Emphasis was placed on voluntary participation, the freedom to withdraw from the study at any time, and their necessary agreement to have the interview audio recorded. Visitors were then asked if they would like to volunteer in this study, which required them to visit the galleries as they normally would. Only visitors who were at least 18 years old were invited to participate. Those that arrived as part of a group were invited to participate, but were asked to complete the log separately. At most, two people from the same group participated in this study. Participants were recruited until 20 completed both the Emotional Response Log and interview. A summary of the demographics is presented in Table 1.

Demographic Variables		**# of Participants**
Gender	Female	11
	Male	9
Age	18-24	4
	25-34	3
	35-44	2
	45-54	5
	55-64	5
	65+	1
Access to smartphone?	Yes	11
	No	9

Table 1. Participant demographics summary

3.1.3. Emotional response log

To provide guidelines for the museum visitors as they visited the galleries, a set of emotions was listed in an Emotional Response Log. An A5-sized booklet, the log was designed to be a portable, yet informative method of capturing visitor responses (see Appendix A). In the log, visitors were instructed to provide their initial emotional responses for up to five different museum artefacts. The log contained the following sections: Gallery Name, Artefact Name, Emotion(s) Felt, and Additional Comments. Within the Emotion Felt section there were six emotions listed: *Anger*, *Disgust*, *Fear*, *Happy*, *Sad*, and *Surprise*, which were taken from Ekman's (1971) research on universal facial expressions of emotions. Two additional options were added: *Indifferent* captured any responses that were neutral and *Other* allowed visitors to write any emotions that were not already listed. In the Emotional Response Log, visitors were asked to indicate one emotion, but some reported that they felt more than one emotion in response to an artefact.

Ekman's basic emotions were selected because he found that these were universal and easily identifiable regardless of culture. The six emotions are also distinct and do not overlap with one another. Furthermore, Ekman has been referred to in museum and archaeology studies related to emotion (Silvia 2005; Tarlow 2000) and his basic emotions have been used in questionnaires concerning emotional responses to artworks (Tschacher et al. 2012). Russell's Circumplex Model of Affect (Russell 1980) was also considered for this preliminary study, but as it comprises two dimensions, it ultimately offered too many options that may be overwhelming to participants during their museum visit (see Appendix B). Self-reported measures were preferred over the more intrusive biometric methods of capturing emotional responses because similar emotion studies that took place in museums also used self-reported measures (Locher, Smith, and Smith 2001; Taylor 2001).

3.1.4. Study procedure

After museum visitors agreed to participate, the Emotional Response Log was provided to each visitor along with instructions for completing it during their visit.

Visitors were assured that they should continue with their visit as they normally would, pausing only when an artefact encouraged an emotional connection to write down any emotions and comments in the log. They were given no time limit for completing the log to ensure that visitors had enough time to see what they intended to see. Visitors were told of a meeting point to reconvene with the researcher once their visit concluded. The meeting point, pre-arranged with the museum staff, was a quiet area of the museum where the structured interview and completion of the demographic questionnaire and consent forms took place.

At the start of the interview, participants were reminded that it would be audio-recorded. After visitors signed the consent form (see Appendix C), which stated that their participation was voluntary and all information was confidential, they completed the demographic questionnaire. Comprised of ten questions, it was intended to obtain an overview of the types of visitors that participated in the study and seek information about whether or not they have access to a smartphone (see Appendix D). Once the forms were completed, the interview commenced. Each participant was interviewed individually.

Each of the five interview questions was designed to give the participants an opportunity to explain why they chose certain artefacts and felt particular emotional responses when viewing them. Further aims were to discover any personal connections and stories visitors remembered while experiencing emotions (see Appendix E for the interview questions). The five questions were based on two main sources. First, questions asking participants to describe how they felt when they saw an artefact, why the artefact made them feel this way, and why an artefact interested them more than the others were modified from a report by Adams and Stein (2004), who assessed visitors' interest and engagement with a museum exhibit. They also asked visitors if they read the exhibit label and whether it affected their response, which was an important question that could identify additional influences for emotional responses.

Another question inquired how strongly participants were affected positively or negatively, which was adapted from Rademacher and Koschel (2006). Although

they concentrated on qualitative market research, they maintained that emotions 'influence thoughts, responses, and actions that follow' and are related to decision making. This question could potentially provide insight on whether participants chose artefacts because of a strong emotional response or whether artefacts were chosen based on other connections.

Information was collected only from visitors who completed the Emotional Response Log and participated in the interview. All data were kept anonymous and given only a number to associate the consent form, Emotional Response Log, demographic questionnaire, and interview responses to the same participant.

3.1.5. Data analysis

Participant interviews totaled 231 minutes, and their responses on the Emotional Response Log provided 26 different emotional responses to 54 unique artefacts. All interviews were transcribed and uploaded into the qualitative data analysis software QSR NVivo 10. Thematic analysis was used to identify patterns in the data by iteratively creating a node in NVivo for each new theme that emerged until no further themes could be found within the interviews (Aronson 1994). The themes were then organised into high-level themes and subthemes using thematic analysis techniques (Ryan and Bernard 2003). The coding scheme was checked for reliability by an external researcher who read a sampling of interviews and coded them according to the scheme; the results corresponded to the original coding and themes.

3.2. Findings and discussion

The goal of this study was to ascertain the types of physical artefacts that encouraged emotional connections, whether the Emotional Response Log and its inclusion of the six basic emotions were feasible for classifying emotional responses, and the themes for their reasoning behind their emotional responses. First, the types of artefacts selected will be examined according to their associated emotional responses from the Emotional Responses Log. Afterwards, the interviews will be analysed to determine what influenced these emotional connections.

3.2.1. Physical artefacts chosen by participants based on their emotional responses

Participants were asked to select artefacts when they felt an emotional response to them. Not all participants were able to find five artefacts that they felt they responded to emotionally, however most did. After categorising the artefacts that were selected by the participants, seven artefact themes were found: 1) Animal-Disassembled; 2) Animal–Intact; 3) Clothing/Accessories; 4) Decorative; 5) Tool; 6) Weapon; and 7) Other. Interestingly, many of these categories are similar to those listed on the European Virtual Museum (2015) website under 'Objects', particularly, 'Animal Figurine', 'Tool', 'Weapon', 'Jewelry', and 'Other'. Figure 8 shows a graph of the total number of artefacts selected in each artefact category.

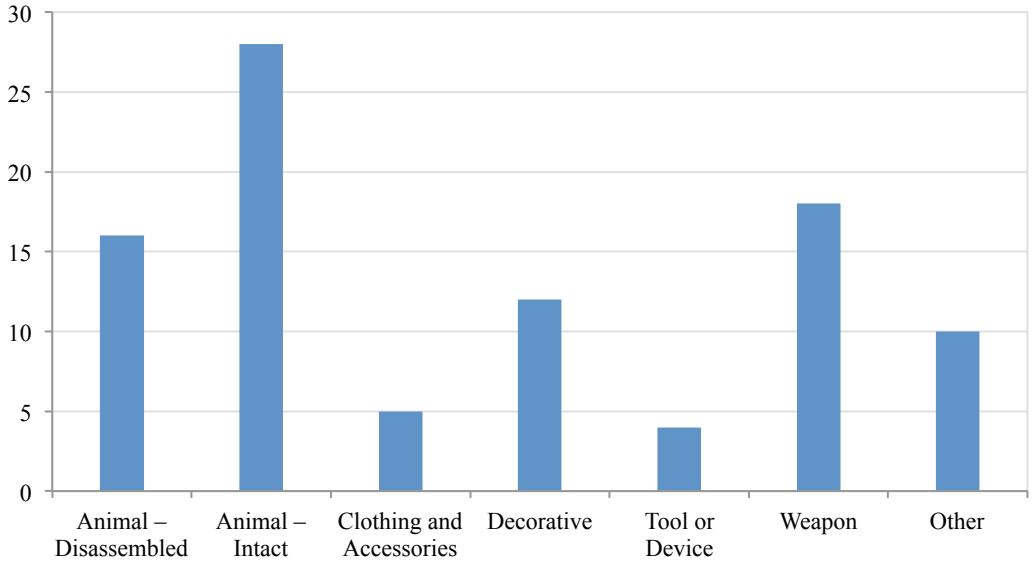


Figure 8. Number of artefacts selected in each artefact category

3.2.1.1. Animal–Disassembled

Artefacts such as the elephant leg bone, skull, tiger's claws, tusks, and the waterbuck head were classified as Animal–Disassembled. As expected, participants felt mostly *Sad*, yet emotions such as *Anger*, *Disgust*, *Happy*, *Surprise*, and *Other* were also experienced by participants (see Figure 9). *Other* here included responses such as *Incredible*, *Impressed*, *Astonishment*, *Enlightenment*, and *Ashamed*. Participants did

not feel *Indifferent* towards these types of artefacts, signifying that this artefact category provoked some type of reaction.

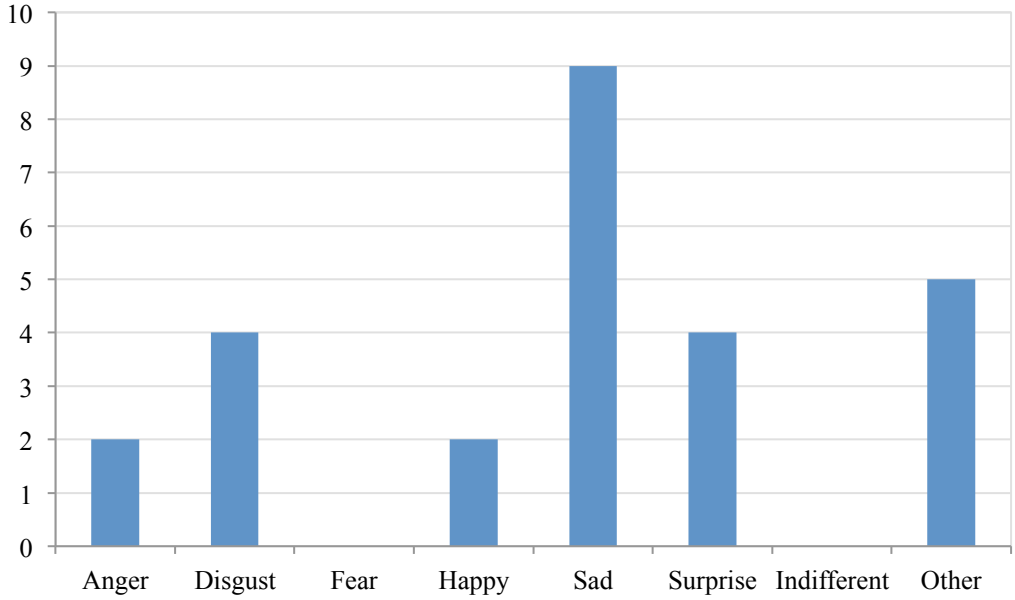


Figure 9. Emotions felt in the Animal-Disassembled category

3.2.1.2. Animal– Intact

Likewise for the Animal–Intact category, participants felt mostly *Sad*, with *Other* and *Surprise* the next highest. However, participants indicated that they felt the rest of the emotions as well, with *Other* representing a wide variety of responses: *Amazed*, *Interested*, *Dismayed*, *Intrigued*, *Death*, *Fascination*, *Awe*, *Memories*, and *Impressed* (see Figure 10). As these responses for *Other* demonstrate, some of the emotions listed were more like remarks, such as when participants wrote *Memories* or *Death*. These were still counted as emotions since they were participants' reactions to the artefacts and what they wrote down in the log. Occasionally, when a participant indicated an emotion of *Other*, the space adjacent to it was left blank. This pertains to all the artefact themes, not just Animal-Intact.

The artefacts in this category were the only ones displayed with a storyline based on their display methods and inclusion of detailed backgrounds. This perhaps led to participants not only choosing many artefacts in this category, but also experiencing

a broad range of responses. Artefacts that were categorised as Animal–Intact include any animal that was complete. This included the elephant, giraffe, hyena, bongo, buffalo, deer, insects, lion, monkeys, and tigers.

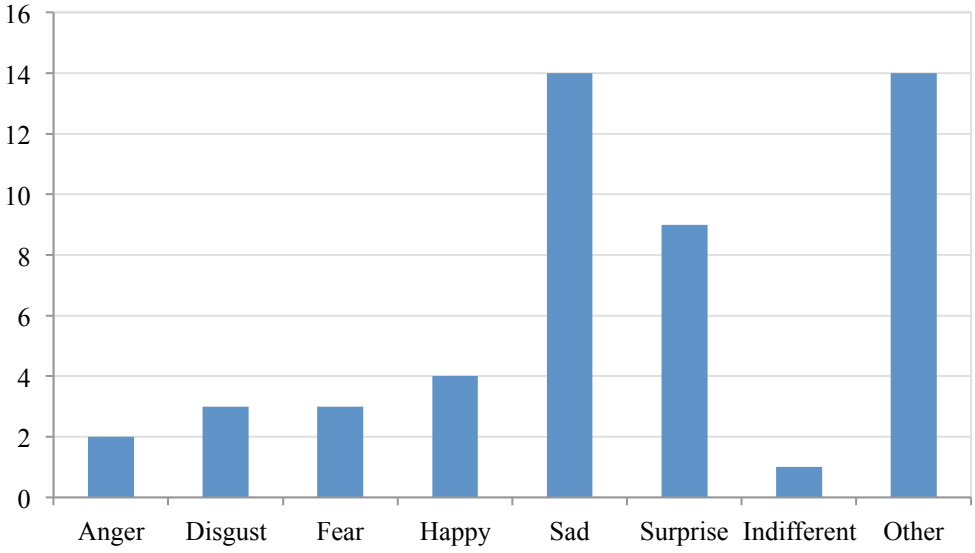


Figure 10. Emotions felt in the Animal-Intact category

3.2.1.3. Clothing/Accessories

For Clothing/Accessories, only three objects were chosen: initiation costumes, lip disc, and wig. Since so few were chosen in this category, these artefacts likely stood out to participants and influenced an emotional response. Figure 11 shows the number and types of emotions felt. Participants felt different types of emotions when viewing these artefacts, with none feeling *Anger* or *Disgust*. *Other* here was listed as *Maternal*.

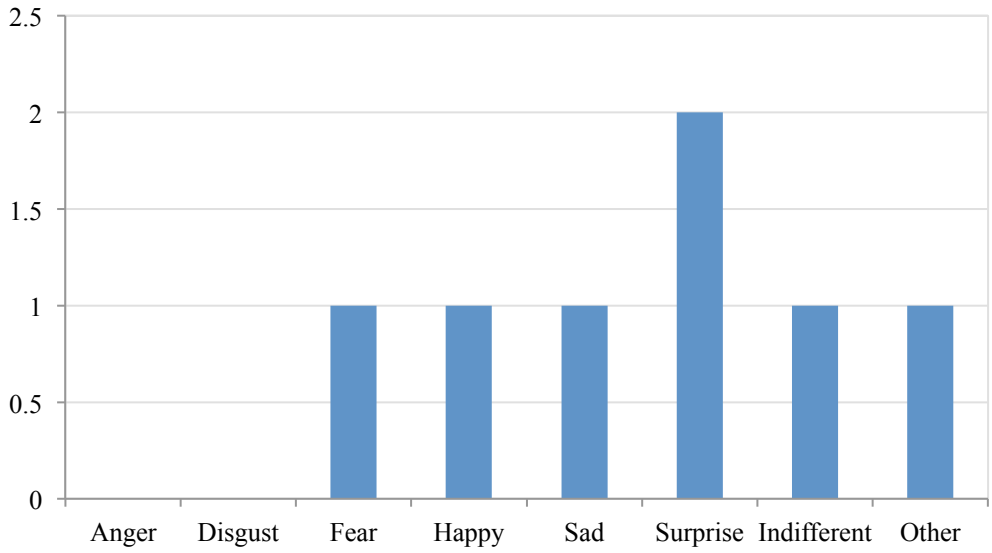


Figure 11. Emotions felt in the Clothing/Accessories category

3.2.1.4. Decorative

Decorative artefacts included an ivory carving, palm leaf mats, photographs, porcelain, pottery, a chair, and bottles. Participants mostly selected *Happy*, *Sad*, *Surprise*, and *Indifferent* as their emotional responses to these artefacts, with *Other* referring to responses such as *Relatable*, *Fascinating, Admiration*, and *Beautiful*. No participants felt any *Anger*, *Disgust*, or *Fear* (see Figure 12).

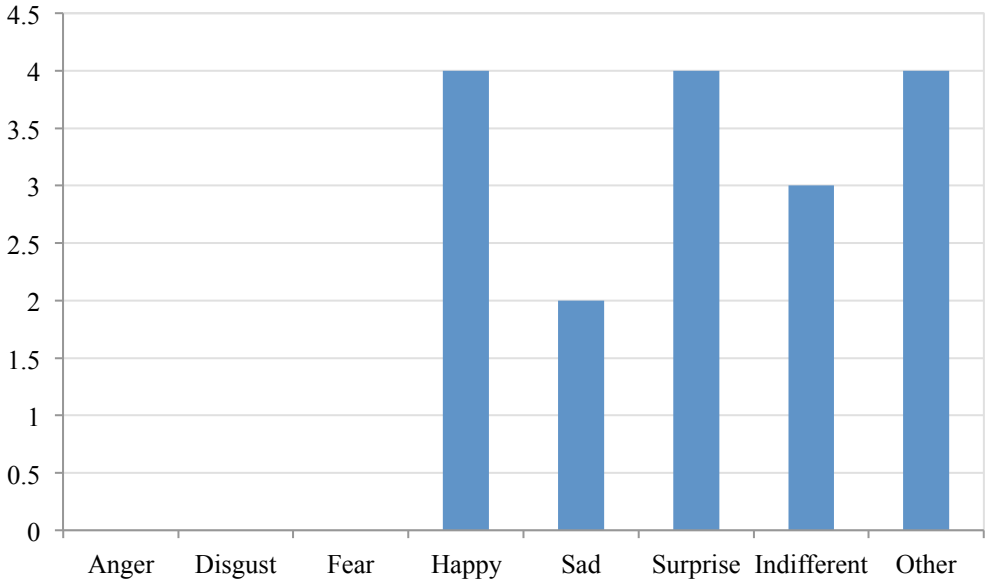


Figure 12. Emotions felt in the Decorative category

3.2.1.5. Tool

Tools that participants selected include a butter churn, loom, water pipe, and ye-bassarathsa, which was a cutting tool. Those who selected these artefacts felt *Surprise* and *Happy*, with *Other* also indicated but left blank (see Figure 13).

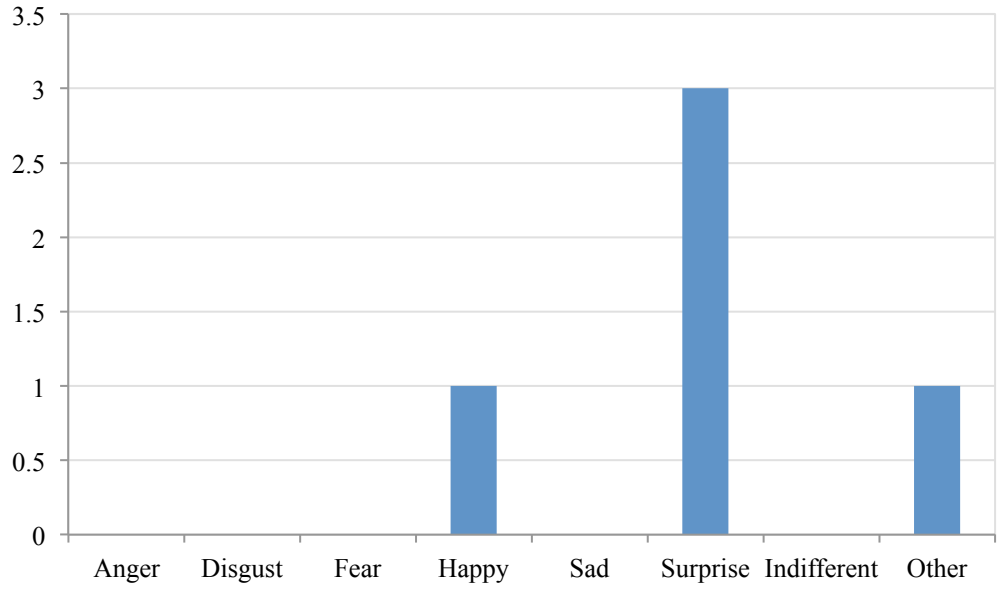


Figure 13. Emotions felt in the Tool category

3.2.1.6. Weapon

Weapons consisted of firearms, daggers, pistols, muskets, a pareng (type of knife), rifles, and a sword. As seen in Figure 14, participants felt a wide range of emotions to weapons, from *Disgust*, *Fear*, *Happy, Sad*, and *Surprise*. *Other* represented *Interesting*, *Amazed*, *Intrigued*, and *Fascinated*. Surprisingly, no one indicated *Anger* in response to these artefacts, and many specified they felt *Indifferent*.

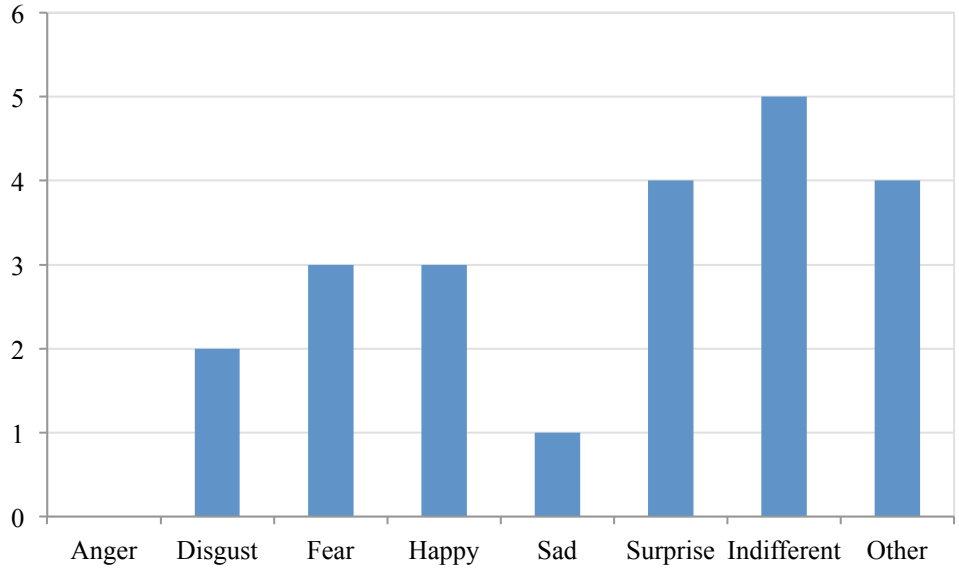


Figure 14. Emotions felt in the Weapon category

3.2.1.7. Other

Artefacts that did not fit into the other categories include a cow horn, gunpowder container, map, model village, a case full of beads, and a toy car. Participants felt *Happy*, *Surprise*, or *Indifferent* when seeing these artefacts, along with *Other*, which signified *Interested* and *Wow* (see Figure 15).

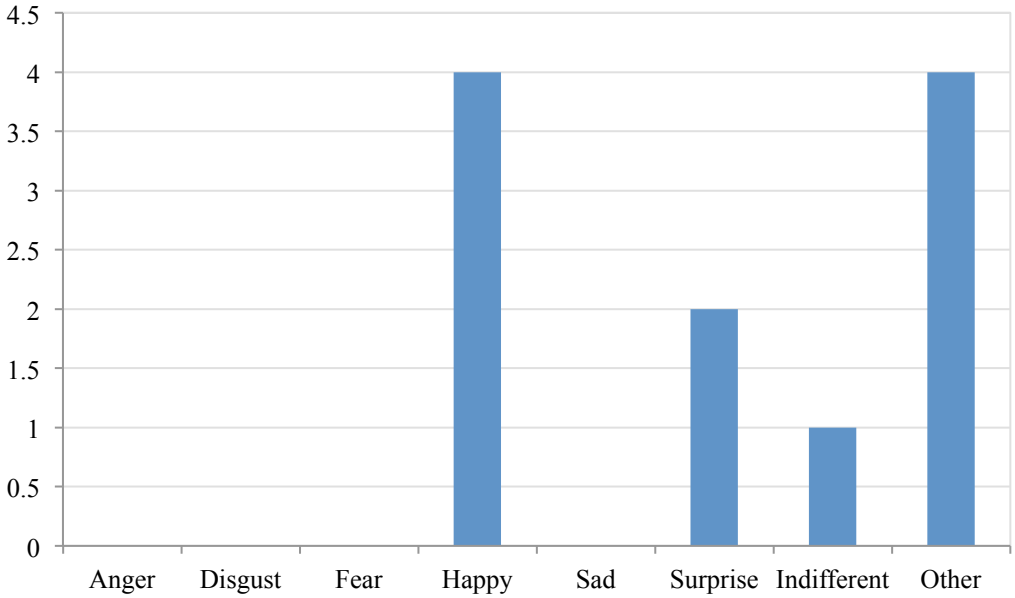


Figure 15. Emotions felt in the Other category

Out of these categories, Animal–Intact had the highest number of emotions, most likely because they were the only artefacts shown in elaborate displays with detailed environments. Figure 16 shows an overview of the number of emotions felt in all the categories.

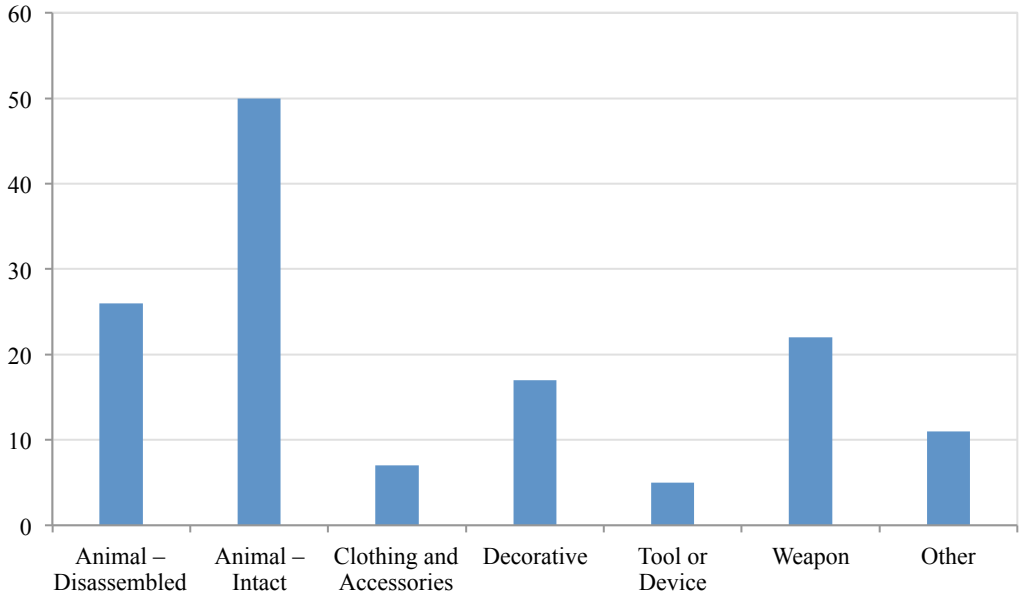


Figure 16. Number of emotions felt in each artefact category

In all, five participants indicated that they felt either indifference or no emotional response to some of the artefacts they chose. Although participants were instructed to select artefacts that they felt an emotional connection to, artefacts were chosen despite their stating no emotional connection, perhaps to fulfill the request to find five artefacts on the Emotional Response Log. The post-museum visit interviews were held to clarify their reasons for feeling emotional responses to artefacts, and this would allow visitors to expand on why they chose certain artefacts even when they indicated no response or *Other* without writing an emotion. Despite some indifference, it can be surmised by the detail and variety of emotional responses that the Emotional Response Log did not interfere with a visit, and as seen in Figure 17, participants utilised Ekman's six basic emotions to indicate their emotional responses. If they needed to express other emotions, the *Other* category was used. To understand why participants made emotional connections with certain artefacts, the interviews were next analysed to identify any themes.

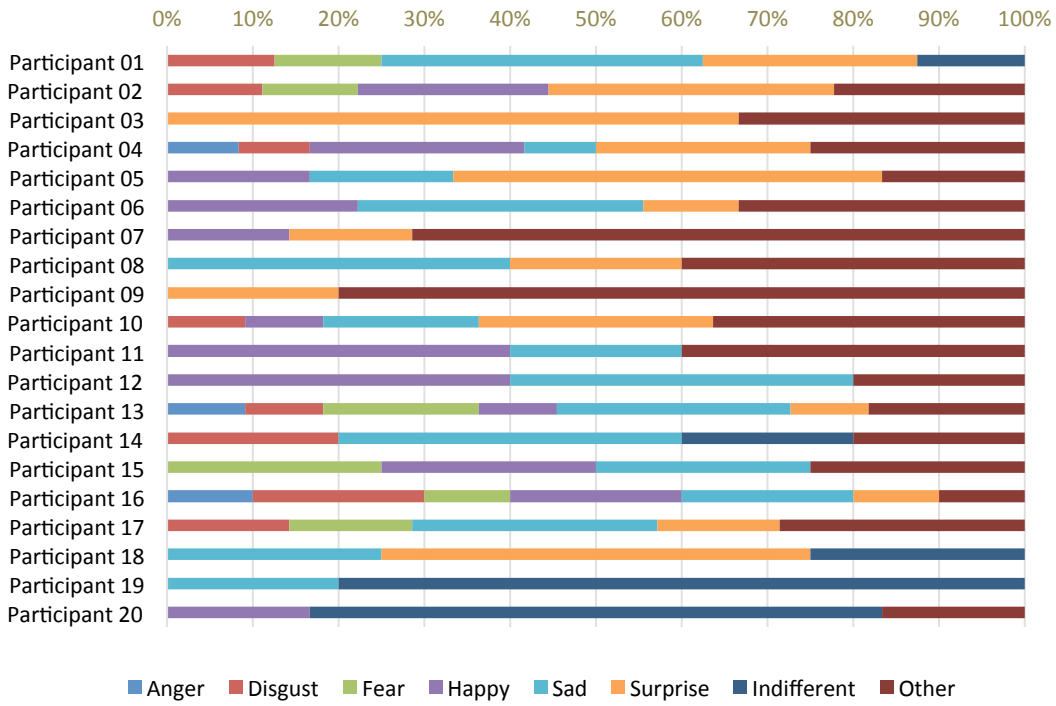


Figure 17. All participants and their emotional responses to the artefacts

3.2.2. Reasons for emotional connections

In post-museum visit interviews, participants were asked questions for further insight into their Emotional Response Log. The themes discovered when visitors described how the artefacts affected them can be categorised into five categories: Attitude Towards the Past, Learning Opportunity, Linking the Past with Present Day Equivalent, New Experience, and Personal History. Each theme represents a personal connection made with an artefact, resulting in the emotion(s) felt, with some categories overlapping to provide unique visitor experiences. More often than not, participants' emotional connections consisted of several themes. The ensuing examples may include other themes, but are used to highlight a few subthemes within an overall theme.

3.2.2.1. Attitude towards the past

The Attitude Towards the Past theme represents visitors' impressions of the time period when the artefacts were collected or created. This can be further divided into

Ethics and Ingenuity, two subthemes that represent the negative and positive feelings towards the past, respectively. Seventeen participants' interviews included references to Ethics while 10 mentioned Ingenuity when speaking about an artefact. Under Ethics, three main arguments occur: Blame, Life Unfulfilled, and Senseless Result. Participants placed blame on several different motives: Educational Purposes, Entitlement, and Ignorance. Some of the Educational Purposes mentioned were for scientific reasons and preservation for the future:

> *"[T]oday's tigers, […] they're not many of them, so whenever you see a tiger that was shot for any purpose whatsoever, it makes you [feel] mixed feelings, sad, obviously at the time it was done, back in the 1800s, 19th century, th[is] was the done thing because people didn't know what impact that would have on nature and the species and everything else…I suppose it was a positive thing, it was done for science […] so that justifies some of it."*

There was a sense of bitterness when visitors talked about Entitlement regarding people who had the means to obtain these types of artefacts:

> *"I would imagine that when [hunter and collector Major Powell-Cotton] set out, at that time it was regarded as a great adventure and there was so much wildlife that they would think, ok, so you kill a couple hundred elephants, so what […]so I think you have to accept what's in the cages is a reflection of its time […] But I suppose if you were representative of the British Empire, you were rich, you did what you wanted to."*

Ignorance was mentioned by 10 visitors, and most references were connected to Blame. In particular, a few stated that in some cases, this ignorance could have led to extinction. Visitors whose emotions were linked to Life Unfulfilled claimed that the ownership of the artefact interfered with a way of life or killed a living being. Fifteen visitors had comments that fell under this subtheme. Last, Senseless Result contains comments relating to how meaningless the resulting artefact was to them

compared to the means required to obtain it, since all that was left were trophies, or as a few participants mentioned, just a head separated from the body.

3.2.2.2. Learning opportunity

Learning Opportunity indicates that visitors either learned new information during their visit or viewed an object that made them think. A total of 19 participants had stories that were related to a learning opportunity, with some gaining knowledge and others providing commentary on why certain artefacts were thought-provoking. Some of these thought-provoking items produced meaningful reflection that connected the design of the artefact with an intended message:

> *"I thought it was a good play on things, first of all, porcelain, quite delicate, and the gun shape, really just contrasting between delicates and violence and stuff like that. I think it was really good because it voiced how a war would be if that makes sense, so delicate like people and stuff, them being the porcelain and the gun shape being the armies."*

Other artefacts raised questions that the museum did not answer through their display or exhibit label, such as how or why an artefact was made or used:

> *"I was a bit dumbfounded as to how it was used. There wasn't enough for me, explanations…why, how it could be used. It was so big, if I was to pick it up I would fall over, so there must be some sort of stand or support system for it, or maybe they put it on their shoulder when they fired it. It's huge, so it's a slight sort-of, hmmm, that's amazing but how do they do it."*

Visitors did not learn new information without also experiencing an additional theme, which is understandable since learning involves the application of the new knowledge.

3.2.2.3. Linking the past with present day equivalent

Linking the Past with Present Day Equivalent explains how visitors either associated an artefact to a modern day equivalent object or task or interacted with a modern equivalent of the artefact viewed. Fifteen participants made this connection between the past and present.

Associations made between the artefact viewed and a modern equivalent typically involved ordinary objects that can be found in everyday life, such as cooking tools, jewelry, pipes, and decorative items:

> *"[I]t was called a meat cutting board, and I was fascinated to see […] it was only the 1900s, but I was so fascinated to see that in those countries that their meat they used actually had a tenderizer on it as well […] and it was being used […]in villages by the women to prepare dinner in the same way we would use in our modern day kitchens."*

Interactions with a modern equivalent were usually situated in zoos or on safaris, where it is common to see comparable animals alive in surroundings similar to the displays.

3.2.2.4. New experience

New Experience describes the different ways visitors experienced something new in the museum; they could have had no prior knowledge of or experience with the artefact, they might see the artefact as unexpected, or they could have had a vicarious experience. This differs from Learning Opportunity because for New Experience, participants described the experience of viewing the artefact compared to past museum visits, memories, or prospective experiences, whereas Learning Opportunity focused on how artefacts were made or their purposes. In total, 12 participants said they had a new experience during their visit. Of that number, most visitors felt they were seeing something they most likely will never see in real life, particularly the

animals. They also imagined themselves picking up the artefacts or using them, which affected the way they felt about the artefact:

> *"[I]n my younger years, days before going to university I did work in various jobs in factories and so therefore I'm aware of spending hours doing a job like that at a machine and also building up skills, so there's a part of me wondering what I would have felt like if I would have been operating the thing and how tired I would have felt, that's all, so there's a bit of empathy with them."*

Some artefacts were unexpected because of their size in the museum, regardless of whether or not they were larger or smaller than expected. Other items were unexpected because visitors thought they seemed out of place within the museum, such as a wig for men. In addition, there were items that visitors had never seen before or did not know exist, meaning they either had no prior knowledge or experience with them. These unexpected and new artefacts positively affected emotional responses.

3.2.2.5. Personal history

Personal History is related to one's identity and includes factors that make each individual different. All 20 participants mentioned stories that fall within this theme, the only theme to involve everyone. The subthemes include Childhood, Job, Knowledge Acquired, and Sense of Self. When visitors recalled memories of their childhood, they usually viewed the artefacts positively, whether the artefact was intact, such as whole animals, or whether it was just a leg bone. One's past job was also brought up by a few visitors as a connection when viewing an artefact, which also affected them positively. Even if the past job was in the army and the artefact led to death, if the deaths had a positive role in history, then the general feeling was positive:

> *"[I]t's a bit difficult to explain, things bring back, when I read, look up things like luger guns I think of all the people the Germans or the SS killed*

with lugers in the war […] so very positive, that's why these things, I know all about these things and what effect they've had on human beings in this world, and what, guns may have a positive role in the war."

Knowledge Acquired was mentioned by 13 visitors and encompasses the following subthemes where they learned prior information: Books, Media (as in TV or Film), Prior Knowledge in General, and School. Artefacts such as weapons and animals were predictably associated with this theme as it is not common to encounter them or learn about them elsewhere. These subthemes encouraged comparisons between what was learned and what was in front of them, prompting a wide variety of emotions. Recognising a version of an artefact from a television show or film seemed to have a positive effect on the visitors, while seeing one from a documentary or news programme had a negative or neutral effect. Sense of Self was mentioned by 13 visitors and includes Family, Female or Motherhood, Opinion or Subconscious, and Residency. Since these are tied to identity, the strength of the emotions felt was strong irrespective of the type of emotion experienced.

Additionally, when asked if they were affected strongly positively or negatively in response to each artefact they chose, the participants felt strongly positive emotional responses to over 50 artefacts. One participant explained:

"Well, for me positively, it was good learning, uh, certainly learning, looking at some of the weapons that wherever you went, [be]cause some of the weapons I've never seen before so, you know, knowledgeable. You know, for India and various other regions which I can't think of at the moment, but like Kashmir and all the other regions that, Sikhs and maharajas that control those regions, had riches of the world, had their own armies, and people don't associate India with war and tribes but there were."

Participants also felt responses that were neutral or not strong to less than 25 of their chosen artefacts, however, they were still affected, as one participant stated:

"It's a thought that will stay with me, I mean, when I meet my friends who are photographers, I will say to them, any idea how this is done, and how it'd been done then, yup, it's one of them, that'll stick with me."

Participants felt strongly negative emotional responses to less than 20 of the artefacts, as one participant recognised the artefacts' purposes, yet still felt sad that animals were killed for display purposes:

"Not to the extent that I cried or anything but just I think both ways in a way, because I think obviously I can see what is there and they are really beautiful creatures as well, but it is at the same time you do think it's really sad that it was, like I said before, they were dead and they were killed just to be viewed really."

To summarise, the five themes represent the reasons why participants felt emotional responses to certain artefacts. Each theme was experienced in all seven artefact categories, indicating that participants were able to emotionally respond to artefacts in each artefact category and had meaningful interactions (see Figure 18). Based on the interviews, participants felt emotions and were meaningfully engaged with and without the aid of descriptive labels. Not including the artefacts pertaining to the Animal-Intact category, artefacts were mainly exhibited without complex display methods, and many of the artefact labels were concise. Therefore, participants made these connections based on their personal backgrounds, memories, and opinions, supporting Hein's constructivist museum (Hein 1998).

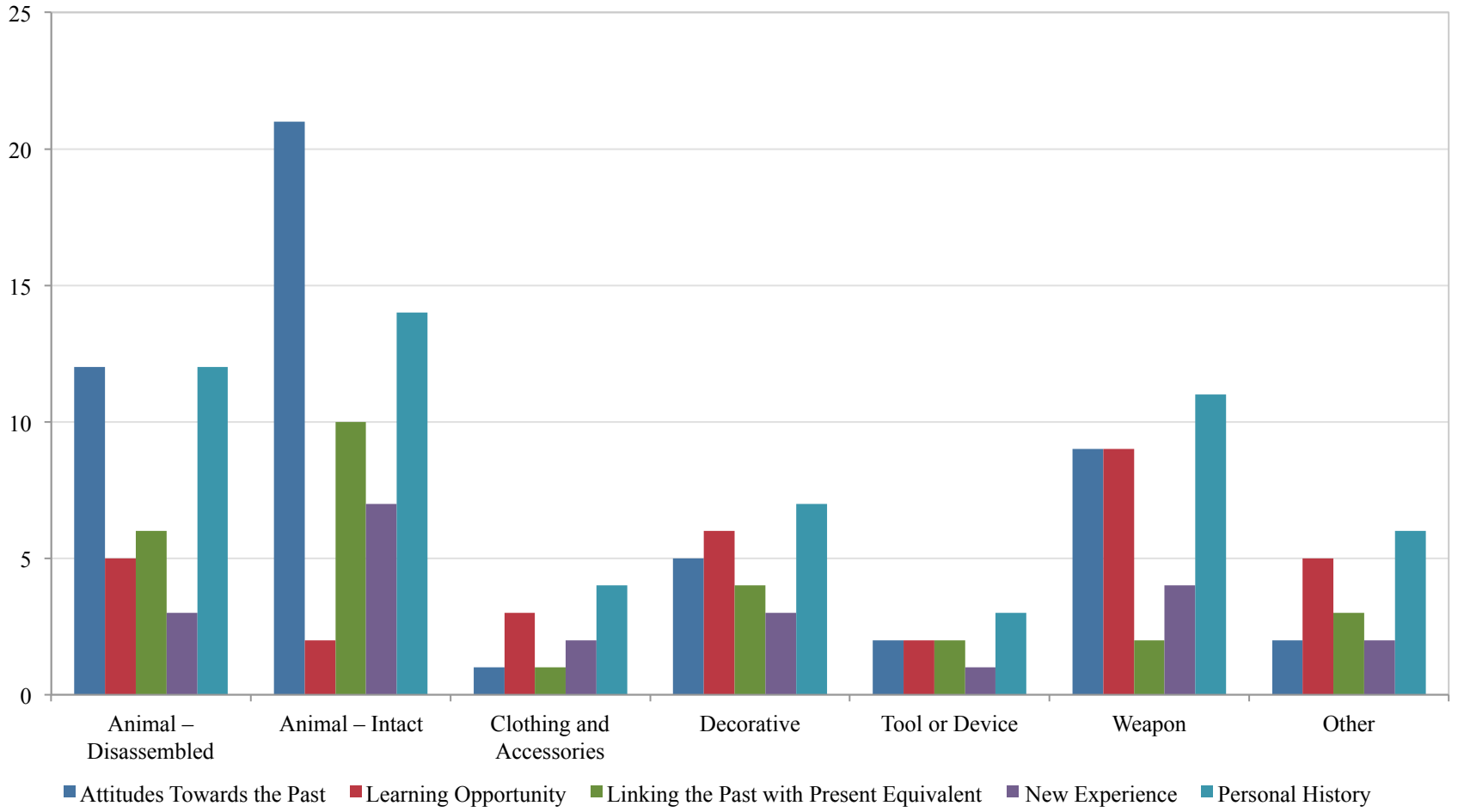


Figure 18. Number of artefacts within each theme

3.3. Conclusion

In general, findings suggest that when given the task of providing emotional responses to physical cultural heritage artefacts, visitors are motivated to find meaningful and personal connections without relying heavily on curators, exhibit labels, and purposeful arrangement of objects (excluding the Animal-Intact category). Additionally, the findings confirm that cultural heritage, ethnographic, historical, and natural history artefacts do influence emotional connections, particularly those in the seven artefact categories identified. Utilising Ekman's six basic emotions in the Emotional Response Log provided sufficient guidelines for participants to record their emotional responses, and the associated themes provided an understanding of how meaning was created, which contributed to their emotions. This knowledge provides insight into how participants might view digitised versions of these types of artefacts since emotional responses and meaning emerged from the viewer-artefact interaction. In the next chapter, the categories of artefacts chosen by the participants in this preliminary study will be used to inform the selection of comparable artefacts to digitise for this thesis' main study, which will ensure that a variety of artefacts are represented.

Chapter 4: Main Study - Methodology for Creating 3D Models and Their Implementation

The previous chapter established that visitors who viewed cultural heritage artefacts in the Powell-Cotton Museum do experience emotions based on connections made from memories, opinions, or personal histories. The themes and the artefacts chosen by museum visitors informed the selection of physical artefacts from the Powell-Cotton Museum's handling collection. The 3D models used in this main study were based on these physical artefacts.

This chapter will explain the process of creating the 3D models and their implementation into two digital modalities. Before digital artefacts can be accessed outside of a museum, they need to be digitised. Many museums already enable access to 3D models of their artefacts through their websites and downloadable AR apps (see section 2.2), thus broadening the audience for their collections. While this study could have considered utilising existing 3D models on museum websites, one of the aims of this study is to compare participants' interactions with digital artefacts in two different modalities, which requires the use of the same 3D model files as on the websites. Depending on the artefact, the files can be rather large, and several different files are required to create a 3D model. This would also create issues concerning the ownership of the files, as they can be duplicated and disseminated digitally (Arnold 2008).

Another aim of this study is to understand how viewing the digital artefacts first affects the subsequent viewing of the physical artefacts. This necessitates access to the physical artefacts as well as the digitised versions, which most likely is a difficult request to fulfil, as many museums may be reluctant to part with their physical artefacts. A museum might choose to digitise an artefact due to its value or fragility, making the physical object itself indispensable and therefore, unavailable for loans. These are reasons why borrowing physical artefacts, along with their existing digital copies, were not feasible for this study. While the Powell-Cotton Museum had artefacts specifically intended for others to borrow and handle, they did not have any 3D models of their physical artefacts. Therefore, 3D models of the physical artefacts

had to be created. The artefacts were acquired not only for digitisation purposes, but also because the physical artefacts could then be used in the main study of this thesis.

Since digitising artefacts is an extensive process, it would take considerable effort, time, and personnel for museums to digitise every single object in their archives. Instead, a select few are chosen by museums based on their purposes. As such, the physical artefacts used in this study were also selected for specific reasons.

4.1. Choosing cultural heritage artefacts

Based on the categories of artefacts chosen by the participants in the preliminary study, which themselves encompassed each of the themes identified from the previous chapter, the following six artefacts were digitised for this study: a baboon skull, a bronze bust, a comb, a gourd, a necklace, and a Kora sword, all on loan from the Powell-Cotton Museum. The Powell-Cotton Museum allowed these particular artefacts to be removed from their collections because they are not on permanent display; instead, they belong to the handling collection. The artefacts chosen fulfilled the categories identified in the previous chapter, except for one. Unfortunately, it was impractical to donate a complete animal, so the Animal–Intact and the Animal–Disassembled categories were combined into one Animal category. Here, the baboon skull represented this category. For the Clothing/Accessories category, a necklace was chosen. A bronze bust corresponded to the Decorative category, while a comb represented a Tool and a Kora sword represented a Weapon. For the Other category, a Gourd was selected. Figures 19-24 show the physical artefacts.

Figure 19. Physical artefact of the baboon skull. Top, side, and overhead view

Figure 20. Physical artefact of the necklace. Front and back view

Figure 21. Physical artefact of the bronze bust. Front, side, and back view

Figure 22. Physical artefact of the comb. Front and back view

Figure 23. Physical artefact of the Kora sword. Front and back view

Figure 24. Physical artefact of the gourd. Two views

Since these artefacts were part of the museum's handling collection, the objects were very portable and therefore not very heavy or large, ranging in height from about 5 inches for the baboon skull to 25 inches for the Kora sword, which was the longest artefact. During the participant sessions, these physical artefacts would be shown along with short descriptions provided by the museum; these descriptions did not include any dates, ages, sizes, or weights, only the title of the object, its background, and materials. Most also included its country of origin. The title for each artefact was kept simple and concise (no more than two words). Table 2 lists the artefacts and their descriptions. Some online 3D artefacts include size, weight, or descriptions in panels alongside the artefacts. Others included this information through clickable points on the artefact, and there were several that either did not include the size or weight or included it by directing users to their website through a link. As this information was not consistent in the websites, it was decided that size and weight information would not be included in the descriptions.

4.2. Considerations for creating 3D models of museum artefacts

There has been considerable research conducted on the topic of digitising cultural heritage artefacts in the form of 3D models (Cakir and Karahoca 2014; Di Benedetto et al. 2014; Singh 2014; Fernández-Palacios, Rizzi, and Remondino 2013; Fang, George, and Palakal 2008; Pavlidis et al. 2007). For these methods, not only were the equipment and specialised knowledge essential, but also sufficient time and the efforts of a team of people. Many museums do not have the staff or budget to digitise artefacts; however, recent software can help change these current methods. These software are available for anyone to use, both professionals and non-professionals, and enable the creation of quality 3D models. It is through these approaches that the physical artefacts were digitised.

Artefact Title	Artefact Description
Bronze Bust	A Nigerian lost-wax method made of bronze. This 20th century piece (identifiable through the way it has been worked, there are power grinder marks on the base) is a replica or tourist version of the types of bronzes made by the cultures centred around Benin
Baboon Skull	This skull represents one of the primate species in the Powell-Cotton Museum's scientific collection
Comb	A traditional style comb from the Cameroons made of wood
Gourd	Made from a plant seed pod and often highly decorated through the carvings or burning patterns on them
	Musical instruments are frequently enhanced with a gourd as a resonating chamber
Kora Sword	Decorated with steel or iron, often with a silvered hilt
	Originated in Nepal but can be found across northern India
Necklace	A bead necklace probably of Southern African origin.
	The many coloured beads either tell a story or biography of the wearer and their family

Table 2. Artefacts' titles & descriptions provided by the Powell-Cotton Museum

4.3. Artefact digitisation process

4.3.1. Overview

In 2011, Autodesk, a suite of 3D design software, released 123D Catch (Autodesk 2013), a free programme requiring only a camera to create 3D models from images quickly and accurately. Due to the availability of Autodesk software to students, the following software was used to create 3D models of all six artefacts: 123D Catch, 3ds Max, and Mudbox. This follows the evaluation of the future of 3D modelling and its museum applications by Metallo and Rossi (2011); although they discussed the difficulties with digitising museum collections, including cost, knowledge, and process, they also recognised that the techniques needed for creating 3D models of museum artefacts already exist.

4.3.2. Autodesk 123D Catch

The first application used was 123D Catch, which relies on photogrammetry, or taking measurements from a number of photographs around an object. Research evaluating its potential was conducted on a large scale for a historical site, as well as on smaller, archaeological objects. Chandler and Fryer (2013) found that 123D Catch was not as accurate as other methods for creating a 3D model of an aboriginal cave site, but upheld its adequacy for many applications that need to capture the relative positions or features of objects. Kersten and Lindstaedt (2012) tested the beta version of 123D Catch, along with open-source software packages, on smaller archaeological objects such as a carved stone and a statue from Easter Island, finding that 123D Catch was the most successful for the stone and had the most photo-realistic result for the statue. Based on these findings, 123D Catch was found appropriate for digitising the six artefacts.

123D Catch has specific requirements for creating suitable 3D models. First, the artefact had to be set on some sort of pedestal that would enable pictures to be taken 360^{o} around it. The artefact also had to be placed over newspaper or other flat material with a unique, non-repeating background. Using a Panasonic Lumix DMC-ZS3, a series of photos was taken every few degrees, all 360^{o} around each artefact. The artefact had to be centred and fill the frame of the photo. Variables such as proper lighting and a diverse background environment contributed to a more accurate 3D model. Typically, around 25-50 photos were needed for a comprehensive model depending on an object's size and features (see Figure 25).

Figure 25. All 43 photos used to create the 3D model of the bronze bust in 123D Catch

These photos were then stitched together using 123D Catch in order to create a 3D model. Since the photos included a background, this had to be removed before obtaining the final 3D model (see Figures 26 and 27). 123D Catch worked best for objects that were more three-dimensional since the pictures taken were truly able to capture more detail in all 360^{o}. The objects that fall into this category were the bronze bust, the baboon skull, and the gourd.

Figure 26. Screenshot of the bronze bust 3D model after all 43 photos were imported into 123D Catch and a majority of the background was removed

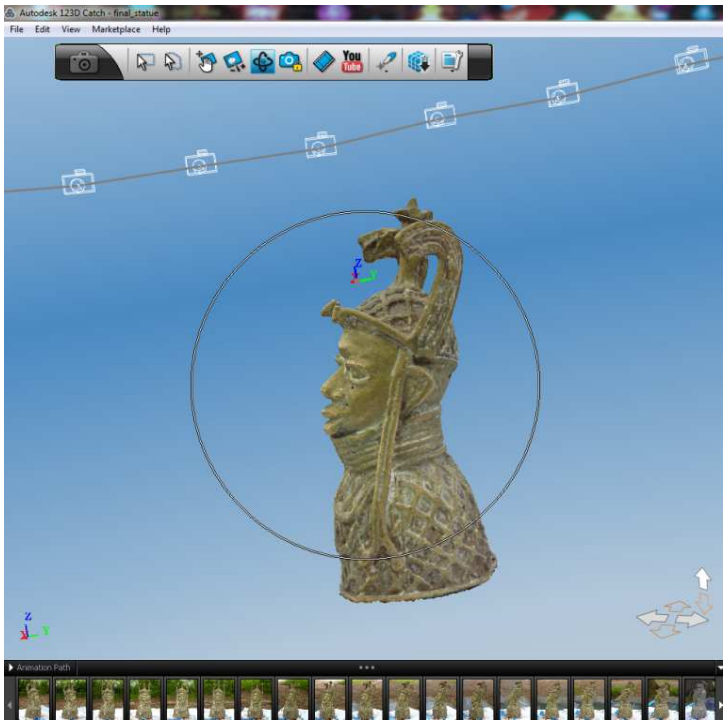


Figure 27. Screenshot of the bronze bust 3D model in 123D Catch after removing the remaining background

Digitising artefacts in 123D Catch still required several attempts before a suitable 3D model was attained. Each attempt included setting up the artefact in various environments with proper lighting, both indoors and outdoors, choosing different backgrounds with non-repeating points that 123D Catch could recognise when stitching together the 3D model, and taking a series of pictures around the artefact to capture every possible angle. These photographs were then uploaded to 123D Catch, after which it was immediately apparent whether the resulting 3D model would be acceptable or not. If none of the series of photos resulted in a satisfactory 3D model, the whole process would be repeated using a different background. An example of an incomplete 3D model of the gourd is shown in Figure 28.

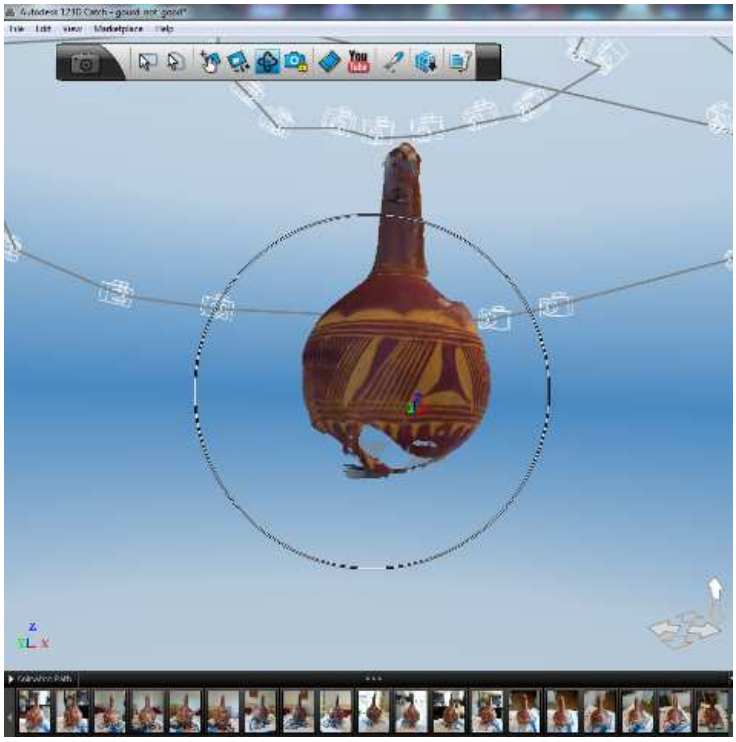


Figure 28. Screenshot of the incomplete gourd 3D model in 123D Catch after removing the background

The remaining objects, the comb, the necklace, and the Kora sword, were two-dimensional and consisted of just a front and back. Due to both the flatness and the level of detail of these artefacts, the software was unable to stitch together a suitable 3D model from the pictures after several tries for each of the flatter objects. Figure 29 shows an example of the resulting 3D model of the comb after uploading images

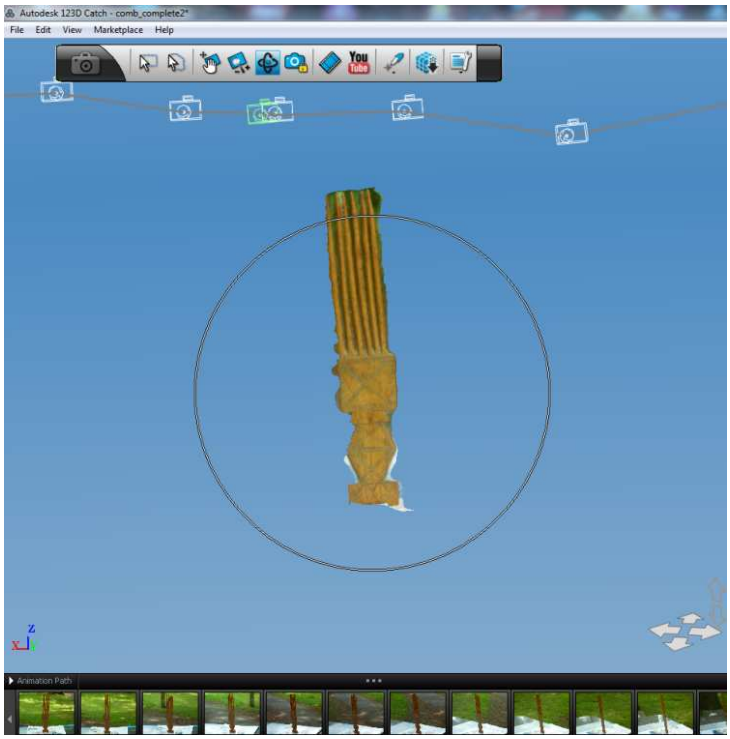


Figure 29. Screenshot of one of the attempts to create a 3D model of the comb in 123D Catch after removing the background

into 123D Catch. Although it looked reasonable from the front and back, it proved to be difficult to match up the teeth of the comb on both sides of the 3D model. Additionally, there would be holes in between each of the teeth that would have to be manually fixed. Due to these complications, 3ds Max was used to reproduce 3D models for the two-dimensional artefacts.

4.3.3. Autodesk 3ds Max

The software 3ds Max was chosen not only for its ease of use, but also because Autodesk offers it as a free download for students. Great care was taken to create accurate 3D models of the comb, Kora sword, and necklace. First, an image of the artefact was imported into 3ds Max and traced to create an outline. The Extrude function was used on the outline to give the model some depth to match the original object (see Figure 30). The model was then converted to an Editable Poly, then mapped for texture (see Figure 31). After the frameworks for the models were created, the pictures were still used to provide the textures for the models, which was necessary to maintain consistency with the models created with 123D Catch.

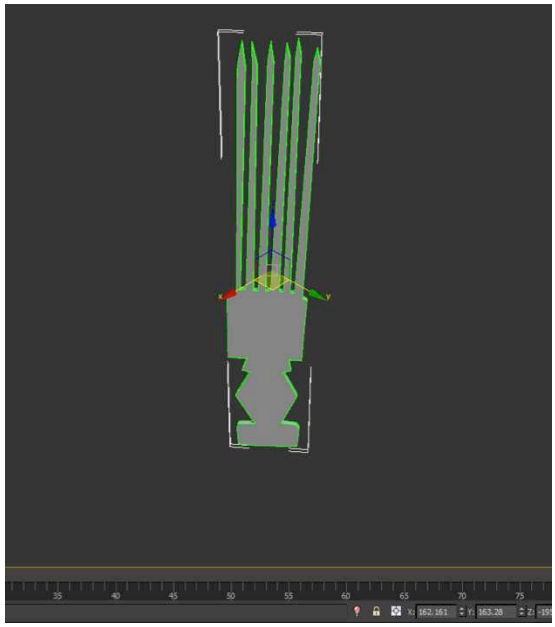


Figure 30. Screenshot of the 3D model of the comb being developed in 3ds Max

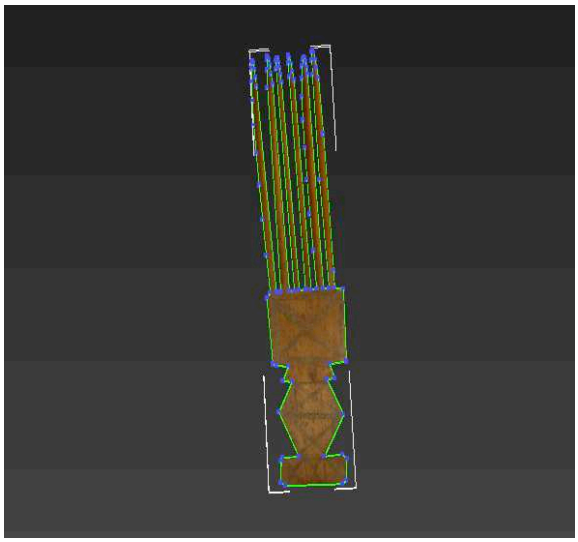


Figure 31. Screenshot of the 3D model of the comb after texture is mapped in 3ds Max

Finally, the files were then imported into Mudbox to smooth out some surfaces and fix any holes (see Figures 32 and 33).

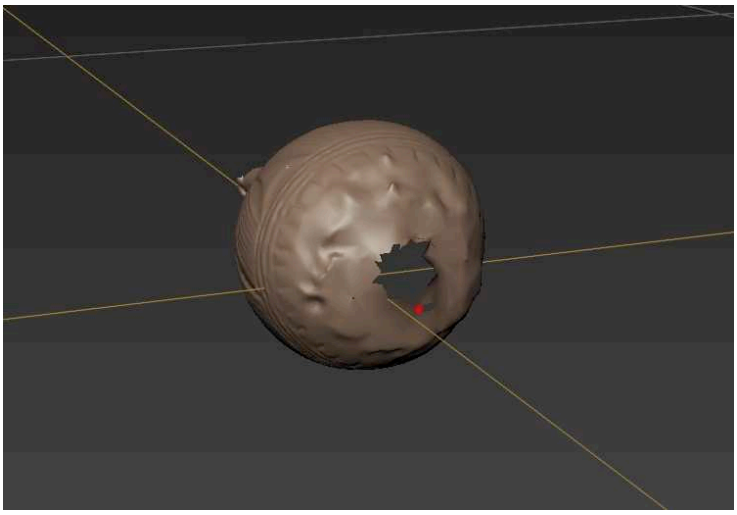


Figure 32. Screenshot before the bottom of the 3D model of the gourd was fixed in Mudbox

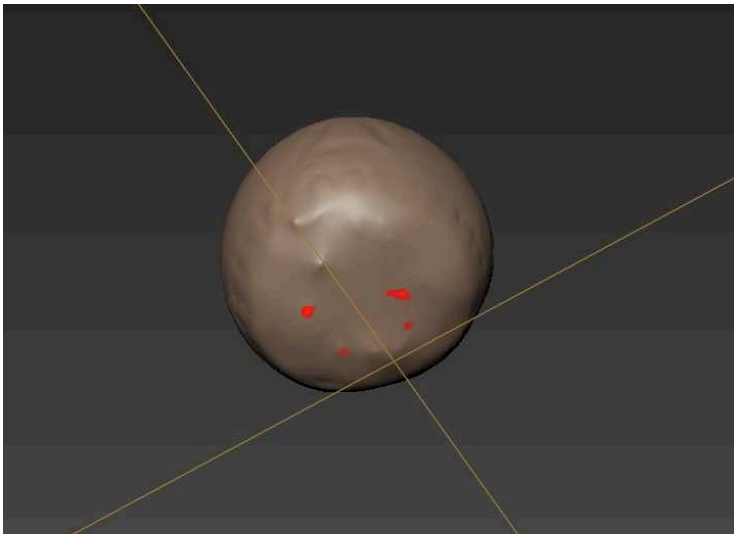


Figure 33. Screenshot after the bottom of the 3D model of the gourd was fixed in Mudbox

After suitable 3D models were created, they could then be implemented into two digital modalities using the object and material files that were exported from both 123D Catch and 3ds Max.

4.4. Digital artefact modalities

As previously discussed in section 2.2.1, several museums have created 3D models of their artefacts and made them available for users to access on their personal devices. Specifically, users can access the 3D artefacts through a website viewable

on a device connected to the Internet or an AR app on a mobile device such as a tablet. Therefore, websites and apps represent two distinct ways museums share their 3D artefacts online, and older and younger adults can access artefacts through these familiar technologies.

Section 2.1.3.2 highlighted how laptops and tablets are considered learning devices for traditional students (Sun, Yang, and He 2014; Norris and Soloway 2011), homebound students (Trentin et al. 2015), and university students (Jacob and Issac 2008). Section 2.1.3.1 discussed how older people use the Internet for health-related information (Harrod 2011), and tablets are being considered as tools that can assist the elderly or disabled with being more autonomous (Castro et al. 2011). Accordingly, older and younger adults' responses to two different modalities are investigated. The tablet was preferred due to its larger screen size compared to a smartphone. The laptop size was chosen for its comparable screen size to the tablet for showing each artefact.

4.4.1. 3D models on a laptop

The first modality was viewing the 3D models on a website using an Apple MacBook Pro with a 13.3-inch (diagonal) LED-backlit glossy widescreen display with a resolution of 1280 x 800. For readability and consistency, this modality will be referred to as 3D models on a laptop for the rest of this thesis. The exported files from 123D Catch and 3ds Max were uploaded to Sketchfab.com (Sketchfab 2013), a website enabling interaction with user-created 3D models in real time. Sketchfab, which launched in 2012, is an online application that allows users to upload 3D content online for free. The 3D models are interactive and can be embedded on websites. Currently, the British Museum (2015a) offers 14 interactive, 3D models of their artefacts online on Sketchfab's website, which users can download, share online, add to their own folders in Sketchfab, and order 3D prints. Some of the 3D models include annotations such as size, weight, and descriptions, while others solely show the artefact.

Since Google Sites offers a free service for creating websites, it was chosen to create the website for presenting the digital artefacts, and Google Chrome was used as the

main browser. A basic website was created for users to interact with the digitised artefacts in a simple, non-distracting environment. Each artefact was embedded on the website using the code provided by Sketchfab, and each artefact's description (see Table 2) was listed underneath it. The artefacts were presented on the default white grid background provided by Sketchfab in two rows of three artefacts each. A black background was used for the website to contrast the white background provided by Sketchfab for the artefacts; this allowed each artefact to stand out. Figure 34 shows the digital artefacts on the finished website. Due to the size of the laptop screen, only one row of artefacts could fully be seen at a time. By default, each artefact is inactive, designated by Sketchfab's logo at the centre of each artefact's viewer. To activate an artefact, users must click on the button in the centre of the viewer. Interaction with artefacts includes rotating the objects, zooming in and out, and moving the artefacts within its viewer.

4.4.2. AR on a tablet

The second modality was the 3D models viewed on an AR app on an Android-based 7-inch Samsung Galaxy Tab with a WSVGA (1024 x 600) display resolution. This modality will be referred to as AR on a tablet for the rest of this thesis. Due to the advancements in creating AR technologies for mobile devices, a few options were considered for creating the AR interface before finally deciding on developing one using Unity (2013) software.

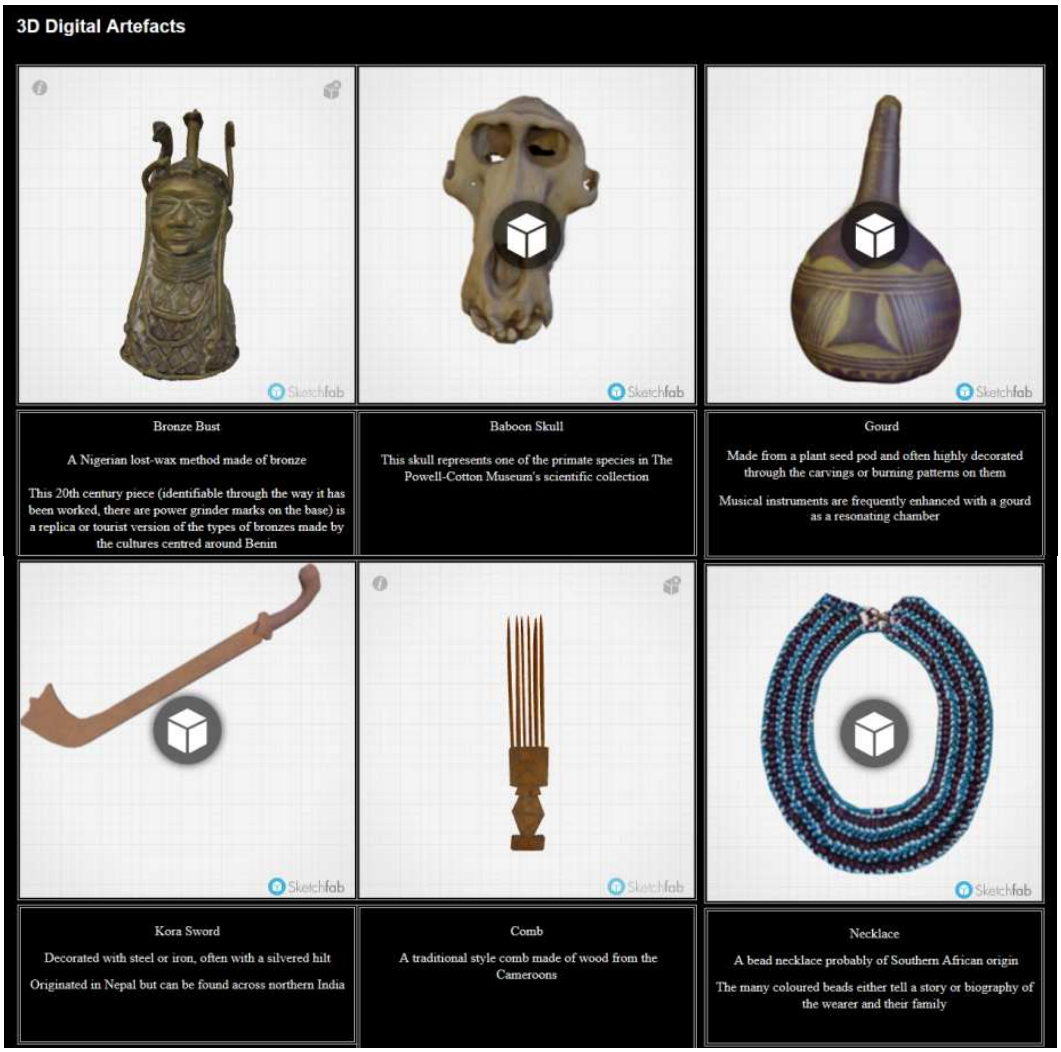


Figure 34. Webpage of 3D artefacts presented on the laptop. Top: bronze bust (activated), baboon skull, gourd; Bottom: Kora sword, comb (activated), necklace

4.4.2.1. Considerations for creating the AR app

A free AR app called Augment (Google 2013), solely used to view 3D objects on an Android, is available on the Google Play market. It allows users to either use pre-loaded 3D models or upload their own. While this app was intuitive to use, the 3D models often disappeared even when the image target was resting on a flat surface.

AndAR (2013) is another free approach for building an AR application on an Android. Its use of a Quick Response (QR) code makes it easy to download, but unfortunately it was difficult to see any of the provided 3D objects. When one of them was finally visible, it tended to disappear after a few seconds and could not be retrieved without going back and re-selecting the object from the selection screen.

The Vuforia (2013a) SDK is a free platform for creating AR applications for the Android OS; however, it involves a complicated process for rendering 3D content. Instead, the free Vuforia AR Extension can be used alongside Unity software. Unity is a game development system that allows the user to create interactive 3D content. This programme allows for greater control over which targets to use, how many targets can be used during the same AR session, and the scale and placement of each 3D object onto the different targets.

4.4.2.2. Unity 4

Due to these reasons, the software Unity 4 was used to create the AR interface. For Unity and the Vuforia Extension to work together, an account on Vuforia had to be created online. It also required that copies of the image targets be saved to the online Vuforia account. Image targets are tangible and can be any non-repetitive pattern. The image targets used in this study had a non-repetitive pattern on one side that was linked to a 3D model; when the AR app recognised an image target, the 3D model was displayed. A different image target was needed for each individual artefact. Six patterns were found online, first by searching for patterns used in other AR applications such as Augment and AndAR, then selecting patterns based on natural elements like rocks and stones (see Figure 35). As the patterns were not related to the 3D models, their variances were only used for the researcher to differentiate each artefact while participants interacted with them.

In Unity, a new scene was created to hold all six 3D models in the application. Multiple image targets could be used in each application, with each 3D model requiring its own image target in Unity. The Vuforia Developer Library provided helpful instructions for compiling the project; these directions were followed to create the AR app (Vuforia 2013b).

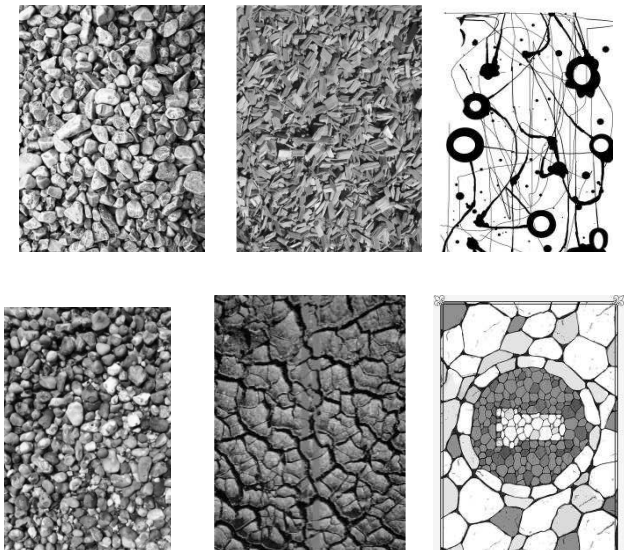


Figure 35. Patterns used for the image targets: (a) bronze bust; (b) comb; (c) gourd; (d) necklace; (e) baboon skull; (f) Kora sword

Using the same files from 123D Catch and 3ds Max, the 3D models of each artefact were uploaded into Unity and associated with a different image target. Each image target was randomly matched with one 3D model. The 3D models were scaled down to fit in the centre of their corresponding image targets (see Figure 36) to ensure that the entire artefact could be seen in the tablet's screen. If the artefacts' sizes were kept relative to each other, users might have to hold the tablet and image targets far apart in order to view the entire artefact on the screen. Textures had to be resolved as often times the incorrect texture was automatically added to a 3D model. Additionally, lighting was added using two Directional Lights, one to illuminate the front and another for the back.

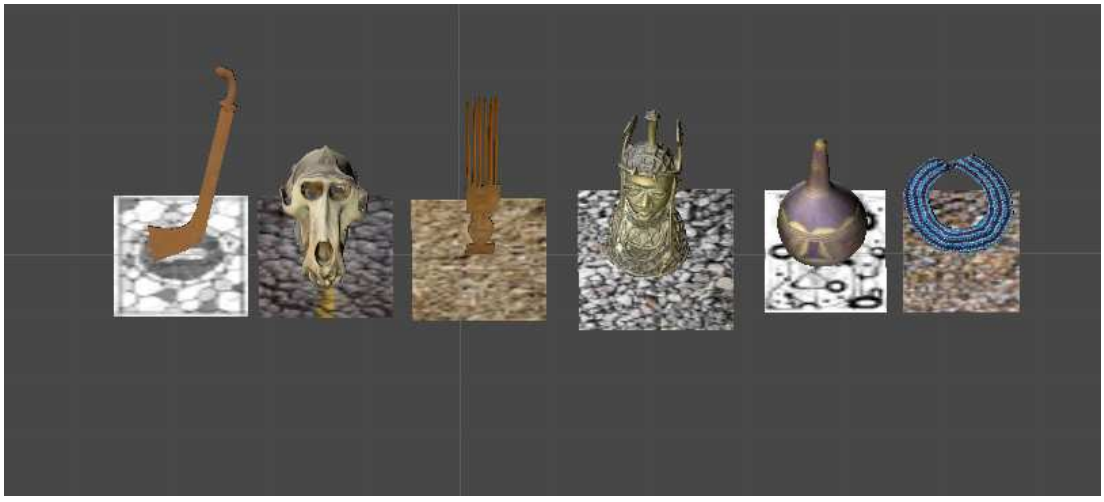


Figure 36. Front view of all six artefacts and their image targets in Unity

Once the image targets and 3D models were finalised, the project was compiled and deployed onto the Android tablet. To view the 3D models, the image targets were printed out and attached to a 2-inch by 3-inch piece of cardboard. The same, short descriptions of each artefact in Table 2 were printed on the other side of the image targets. Although the image targets in Unity were in colour, the app is able to recognise patterns whether they were in colour or black and white. To maintain consistency, all image targets were printed out in black and white. Similar to the 3D models on a laptop modality, users could interact with the artefacts by rotating them, zooming in and out, and moving them via the image target.

4.5. Comparison of physical and 3D models of artefacts

Figures 37-42 show a comparison of the physical artefacts, the final 3D models in Sketchfab for the website, and the final 3D models along with their image targets in Unity for the AR app. Since the photos used to create the digital artefacts were taken in optimal environments that had busy backgrounds, which were necessary for capturing accurate 3D models, the physical artefacts are shown here with the same, neutral background for consistency. This may account for any differences among the same artefacts in lighting and colour. See Appendix K for the url for the website used in the main study and the files used for the AR app and 3D models.

Figure 37. Physical baboon skull (left); 3D baboon skull in Sketchfab for the website (middle); 3D baboon skull in Unity for the AR app (right)

Figure 38. Physical necklace (left); 3D necklace in Sketchfab for the website (middle); 3D necklace in Unity for the AR app (right)

Figure 39. Physical bronze bust (left); 3D bronze bust in Sketchfab for the website (middle); 3D bronze bust in Unity for the AR app (right)

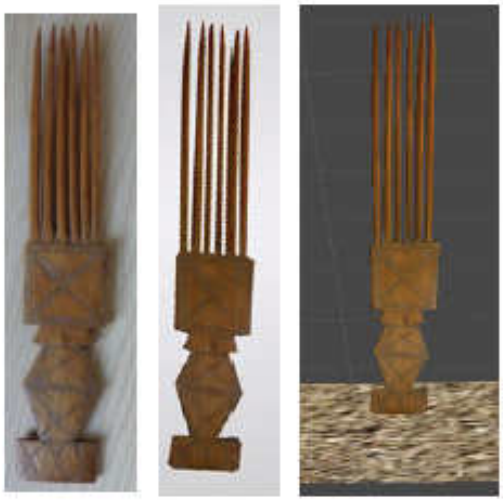


Figure 40. Physical comb (left); 3D comb in Sketchfab for the website (middle); 3D comb in Unity for the AR app (right)

Figure 41. Physical Kora sword (left); 3D Kora sword in Sketchfab for the website (middle); 3D Kora sword in Unity for the AR app (right)

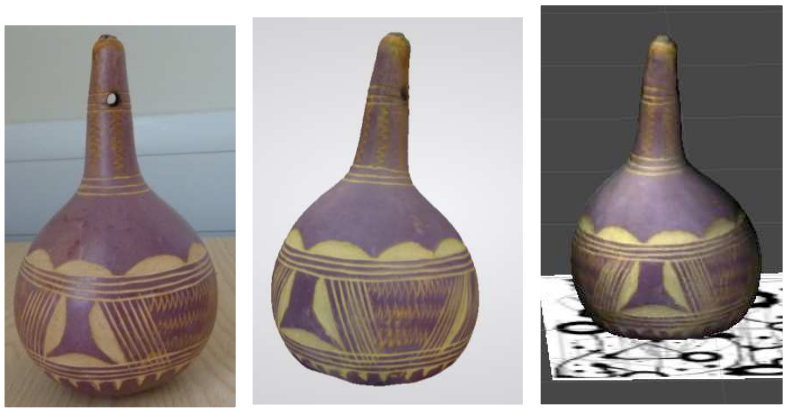


Figure 42. Physical gourd (left); 3D gourd in Sketchfab for the website (middle); 3D gourd in Unity for the AR app (right)

4.6. Conclusion

This chapter described the process for creating 3D models of six different artefacts from the Powell-Cotton Museum and their implementations into a website and AR app. While several options were considered, the software decisions were essential in creating inexpensive yet suitable 3D models. These digital modalities will be utilised in the main study procedure described in the next chapter.

Chapter 5: Main Study - Methodology for Participant Selection and Procedure

The previous chapter explained the procedures for selecting six different artefacts from the Powell-Cotton Museum, determining the optimal methods to develop the 3D models, digitising the artefacts by creating 3D models, and deciding how to integrate them into two digital modalities, a website on a laptop and an AR app on a tablet. Final 3D models were developed using 123D Catch, 3ds Max, and Mudbox, and then implemented in two digital modalities using Sketchfab, Google Sites, Unity, and Vuforia software.

This chapter will describe the methods for the main study of this thesis. As this study focuses on older and younger adults and how emotion and meaning arises from interactions with digital artefacts on personal devices, the results will provide the data needed to answer the research questions. This chapter first presents an overview of the study, then clarifies the process for selecting participants and approaches for collecting data. The procedure for each participant session, including the details of the digital and physical artefact modalities, is also described.

Although 3D artefacts are the focus of current museum research and technology (see section 2.2), a greater understanding is needed on interaction with 3D artefacts outside of a museum, particularly whether people are able to respond emotionally and make meaning, as emotion and meaning are considered important aspects of a museum visit (see sections 2.4 and 2.5). This main study will explore two diverse groups of museum visitors with different technology skills, older and younger adults. Understanding older and younger adults' emotional connections with 3D artefacts and the way they construct meaning can therefore provide insight into how different types of museum visitors, along with people with varying technology abilities, respond to digital artefacts. This study was reviewed and approved by the Faculties Support Office at the University of Kent on 19/08/13 and was conducted between August and November 2013.

5.1. Study overview

This main study was a within-subjects study using counter-balancing in order to minimise order effects. The location for each participant session was at the School of Engineering and Digital Arts at the University of Kent. In total, each participant session consisted of three artefact modalities, all consisting of the same six artefacts: 1) First, viewing and interacting with the six artefacts presented in either 3D on a laptop or AR on a tablet; 2) Second, viewing and interacting with the six artefacts presented in either the 3D or AR modality depending on what was shown first; and 3) Third, viewing, without touching, all six physical artefacts, which is usually how visitors would interact with an artefact in real life while at a museum.

5.2. Participant selection

When recruiting participants, specific ages were required for both groups. While museum studies focused on varying age brackets for older people (NEA 2015; Hanquinet and Savage 2012; McIntyre 2007), the ages for the older adults in this main study were based on previous research presented in section 2.1. Furthermore, the traditional default retirement age is 65, a stage in life when older adults have more free time. Choosing to focus on this age group will provide an understanding of their interaction with museum objects using innovative technologies. Moreover, insight from participants who represent the largest sector of museum visitors can determine how accessing digital artefacts through various technologies leads to emotion and meaning, two important aspects of a physical museum experience.

Likewise, museum studies (NEA 2015; Hanquinet and Savage 2012; McIntyre 2007) reported different ranges for young adults. For this main study, focus was placed on young adults aged 18 to 21. As section 2.1.4 explained, young people are typically considered adults at age 18, and this is when they usually attend university or seek employment. By the age of 21, students usually graduate university. During their time at university, they are likely to use technology such as laptops and tablets for learning (see section 2.1.3.2). Therefore, this formative age group, who are among those that visit museums the least, could provide discerning feedback on how

engaging the technologies are and their thoughts on various representations of digital museum artefacts.

Due to specific age requirements, several outlets were used to recruit participants. Older participants were selected through recommendations from colleagues, invitations by email to people on-campus at the University of Kent and from the Kent Adult Research Unit (KARU), an initiative aimed to involve the local public in research, and visits to lunch-time gatherings attended by older people in Canterbury. Since the ages for the younger participants were based on university ages, a majority of them were undergraduate students at the University of Kent. They were recruited through emailed announcements, recommendations from colleagues, and discussions with people on-campus.

A total of 40 participants volunteered for this main study, of which 20 were older people aged 65 and over, and 20 were younger people aged 18-21. Furthermore, half were female and half were male for both age groups. Participants were all proficient in the English language, either being UK citizens or attending UK universities. The first 40, eligible people who responded to advertisements and whose schedules coincided with available session times were selected to participate. The decision to recruit 40 volunteers was based on several studies that compared digital and physical modalities using the same participants. A total of 12 volunteers were used in Terrenghi, Kirk et al.'s (2007) study comparing physical and digital media on interactive, table top surfaces, evenly split between males and females. Lee, Luo, and Ou (2009) had 17 participants in their 2D modality, of which 7 went on to participate in the 3D modality. Both studies used statistical analysis to compare the modalities. Additionally, the studies that used different groups of participants for the digital and physical modalities, along with statistical analysis to evaluate their data, used 20 participants in each group (Locher, Smith, and Smith 2001) or less than ten (Quiroga, Dudley, and Binnie 2011). Since this study compared two age groups, a goal of 20 participants for each group was set, each having an equal number of male and female participants. Participants were volunteers; they were offered no compensation in return for their contributions, with the exception of parking passes if required.

The same participants were used for all three artefact modalities with the purpose of understanding their differences in each digital modality and how their responses compare when finally seeing the physical artefacts. Furthermore, the decision to use the same participants for all three modalities was based on previous, similar studies. Specifically, Terrenghi et al.'s (2007) study comparing physical and digital media on interactive, table top surfaces used the same participants for both tasks. This method allowed the researchers to identify the main differences in usability and make recommendations for designing interactive surfaces. Another study compared digital and physical objects and focused on affective feelings, except they determined how properties such as colour and shape were influential (Lee, Luo, and Ou 2009). Participants were shown different 2D shapes, each with a different colour, and based on consistency of their responses, some of the same participants continued on to assess the 3D shapes. Although the total number of participants was different in the 2D modality, the 3D modality used participants who had already seen the 2D shapes. Comparable museum research had separate groups for each of the digital and physical modalities (Quiroga, Dudley, and Binnie 2011; Locher, Smith, and Smith 2001) or used the same participants, each viewing the same artwork but in varying modalities (Taylor 2001). However, they did not investigate the effects the digital modalities might have on subsequently viewing the physical object. Therefore, this informed the decision to use the same participants and artefacts for each modality in this thesis.

5.3. Data collection

All participant sessions were one-on-one and held in the same location on the campus of the University of Kent. The two age groups and three artefact modalities were the independent variables, while the data collected, including the time spent within each modality, ranking of enjoyment, emotion, and meaning, were the dependent variables.

5.3.1. Consent form

Upon arriving to their session, participants were greeted, briefed on the study, and notified that the study required them to be video recorded. They were then given a

one-page consent form that explained the reasons for the study, the tasks involved, and its confidentiality. The form also included a reminder that participation was voluntary and participants could leave the study at any time. If they agreed to participate in the study, they printed and signed their names along with the date. A copy of the consent form is located in Appendix F.

5.3.2. Video recording

During the main study, each participant was seated behind a desk with either a laptop or tablet, depending on the modality. A video camera was set up in front of the desk, which faced the participants. This was to record not only the participants and what they said, but also the image targets for the AR on a tablet modality, the laptop in the 3D models on a laptop modality, and the physical artefacts. Since only the back of the laptop could be seen in this set-up, the activity on the laptop screen was recorded using QuickTime software. The video and laptop screen recordings were also necessary for measuring how much time participants spent with each artefact, and therefore each modality. Due to the screens of the laptop and tablet facing away from the video camera and researcher, participants were asked to state the artefact they were looking at before they started talking about it.

5.3.3. Demographic questionnaire

All participants completed a demographic questionnaire at the beginning of their session; this requested information about their familiarity with 3D virtual objects, familiarity with AR, frequency of museum visits in the past 12 months as well as frequency of viewing museums' collections online in the past 12 months. The demographic questionnaire was based on England's Household Questionnaire for the 2011 Census (Statistics 2011). Due to different education options for the older and younger people, they were given slightly different questionnaires that asked specific questions about either their highest level of education completed (older adults) or degree and course of study (young adults). Examples of the Demographic Questionnaire for older and younger participants can be found in Appendix G.

5.3.4. Artefact modality questionnaires

After each artefact modality, participants were asked to complete a questionnaire with a Likert scale and space to write in answers. First, the questionnaire asked them to rate how enjoyable the experience was based on a scale from 1 to 10, with 10 being the highest enjoyment. This question was included to determine whether participants found the 3D models on a laptop or the AR on a tablet modality more enjoyable, and also to establish whether they still found the physical artefacts modality enjoyable after seeing the digital artefacts. The scale range was chosen to provide more options for the participants so an accurate ranking can be obtained. Similar ranges (between 7- and 9-point scales) were used in self-reported rankings comparing digital and physical artworks, which included some emotional responses such as surprising, interesting, and pleasant along with their opposite responses (Locher, Smith, and Smith 2001), comparing affective feelings to 2D and 3D objects (Lee, Luo, and Ou 2009), and identifying emotional experiences when viewing artworks inside a museum (Desmet, Hekkert, and van Erp 2009). Next, if participants felt any emotions while viewing and interacting with an artefact, there was space to write down any artefact names next to a list of eight different emotions. Based on the Emotional Response Log from the preliminary study described in Chapter 3 (see Appendix A), the emotions consisted of the six basic emotions taken from Ekman's research: *Anger, Disgust, Fear, Happy, Sad,* and *Surprise* (Ekman 1971), along with options for *Indifferent* and *Other*. The findings from the preliminary study indicated that participants utilised Ekman's basic emotions, which led to a variety of responses to artefacts within the same category, but also provided additional emotions when necessary. The basic emotions were therefore used again as guidelines for participants. Last on the questionnaire were spaces for participants to state which artefact they liked the most and the least along with their reasons why. Please see Appendix H for the artefact questionnaires.

5.3.5. Emotional intelligence questionnaire

At the end of each session, participants were asked to complete a one-page Emotional Intelligence Questionnaire developed by Schutte et al. (1998) to determine if they had 'the following three categories of adaptive abilities: appraisal and

expression of emotion, regulation of emotion and utilisation of emotions in solving problems'. Emotional intelligence 'involves the ability to monitor one's own and others' feelings and emotions' and is initiated when 'affect-laden information first enters the perceptual system' (Salovey and Mayer 1990). The use of this questionnaire would help clarify if participants' emotional intelligence influenced their responses during the study. The Emotional Intelligence Questionnaire can be found in Appendix I.

5.4. Participant session procedure

After completing the consent form and demographic questionnaire, participants could continue with the study and interact with the digital artefacts. For the first digital modality, half of the participants were randomly given the 3D models on a laptop and half were randomly given the AR on a tablet. Not only were participants divided by age in each modality, they were also equally split by gender. Both age groups were given instructions on how to interact with the artefacts using the laptop or tablet and were told where the artefact's information was located. Participants in this study were asked to sit on a chair for all three modalities to maintain consistency and enable the video camera to record every comment and interaction with the artefacts.

Participants were shown all six artefacts in the three modalities for consistency. Rather than follow the procedure used by Taylor (2001), which required each participant to view the same 20 artworks but in varying modalities, this study showed fewer artefacts. Since this study compared participants' responses when seeing the physical artefacts after the digital artefacts, it was crucial that the participants saw the same artefacts in each modality. If, by chance, only one artefact prompted an emotional response in one modality but was not shown in other modalities, it would signify that one modality may have been more successful in encouraging emotional responses, when in actuality it was the artefact itself. This could lead to incorrect data for participants' responses to artefacts in each modality.

To represent the experience of viewing digital museum collections before viewing the physical artefact, the digital artefacts were always shown first and the modality

with the physical artefacts was shown last. However, while participants were always shown the physical artefacts third, they were randomly shown either the 3D models on a laptop or the AR on a tablet first, then the remaining digital format second. The physical artefacts were taken out of the museum setting to ensure that each modality of artefacts would be shown in the same space, allowing participants to evaluate them under consistent conditions. Since past researchers have indicated that the museum environment can influence emotions (Locher, Smith, and Smith 2001; Gadsby 2011; Taylor 2009), showing all the modalities, including the physical modality, outside of the museum can further demonstrate that viewing or interacting with only artefacts can lead to emotions and meaning.

Utilising the think-aloud method (Charters 2003), participants were asked to state the artefact they were currently looking at, as well as verbalise and explain their actions, thoughts, feelings, associations, or memories as they viewed and interacted with the artefacts. Allowing participants to interpret the artefacts based on their own knowledge and backgrounds follows the constructivist approach (Hein 1998). They could choose the artefacts in any order. Prompts were used in case participants did not have a lot to say, such as "Why did you choose that artefact (first / second / next / etc.)?", "Can you comment on the aesthetics/attributes of the artefact?", and "You did not talk about this artefact, can you explain why?" The think-aloud method was utilised in this main study primarily because it was the main method for collecting data in similar studies that explored visitor responses to museum collections (Mortensen 2011; Laberge 2010), including emotional responses to museum artworks and objects (Housen 1999; Dufresne-Tassé and Lefebvre 1994).

5.4.1. 3D models on a laptop modality

In the 3D models on a laptop modality, users interacted with the artefacts using a mouse connected to the laptop. To maintain consistency with the size of the tablet screen, participants were asked not to maximise the browser window for each individual artefact and instead interact with the artefacts in the given viewer space. They were also told they did not have to interact with the artefacts in the order they were presented. Using the mouse, users could rotate the artefact, move it to another area on the screen within the artefact's space, and zoom in and out. The website had

no reference to the Powell-Cotton Museum or other context besides the short titles and descriptions provided by the museum (see Table 2). Information about the actual size or weight of the artefacts was not listed, partly because some online 3D artefacts do not include this, or museums make the information available through a link directing the user to the website for more information. Although there were six artefacts, only one row of three artefacts could be seen at a time, and users had to scroll down to view the remaining three artefacts. Figure 43 shows the default view of the top row of the website; in this example, a participant is interacting with the bronze bust.

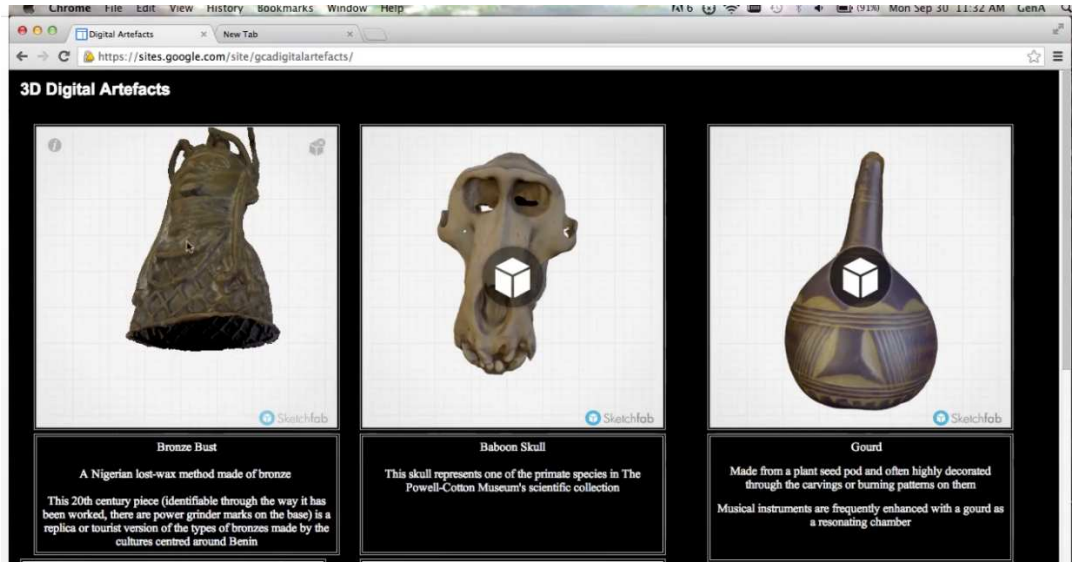


Figure 43. Screenshot of a participant interacting with the bronze bust in the 3D models on a laptop modality

After participants finished interacting with this digital modality, they were given an artefact questionnaire asking them to rate the experience on a scale from 1 to 10, with 10 being the highest enjoyment, write down the names of artefacts next to a list of eight different options if they felt any emotions, and state which artefact they liked the most and the least along with their reasons why.

5.4.2. AR on a tablet modality

The other digital modality is interacting with artefacts through AR on a tablet. In this modality, all six image targets were lined up randomly on the table and participants were told they could choose them in any order. Although the tablet is

considered a mobile device, participants were asked to sit while they interacted with artefacts in this modality to maintain a consistent set-up with the 3D models on a laptop modality, thus enabling the video recording to capture all movement and comments. Using the tablet, users could manually rotate the artefact through the image target, zoom in and out, and move the artefacts anywhere they wanted to on the table. While the tablet was capable of recognising more than one image target at a time, participants were not informed of this as viewing too many artefacts at once might cause the AR app to freeze. Nonetheless, few participants attempted this and usually only viewed one artefact at a time. The screen size and level of detail they wanted to see most likely played a factor in this as well. Similar to the website, the AR app did not include any mention of the Powell-Cotton Museum or size and weight data, but unlike the website, the titles and descriptions of the artefacts were not shown alongside the artefacts. Instead, they were printed on the other side of the image target to keep descriptions linked to the artefact. When downloading an app in real life, the website may only give an overview of an app's purpose and may or may not include screenshots, so users might be are less aware of an app's capabilities compared to the website. Relatedly, participants in the AR on a tablet modality did not know which artefact they would be seeing based on the image target unless they chose to first read the description on the back of the image target. Figure 44 provides a view of the image targets being used to interact with artefacts on the tablet.

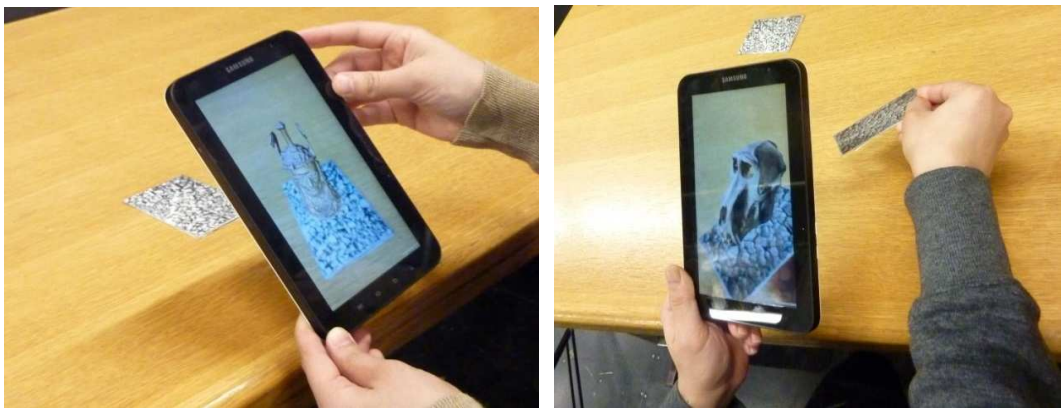


Figure 44. Interacting with the AR on a tablet modality

Just as in the 3D models on a laptop modality, participants were asked to complete an artefact questionnaire after they finished interacting with artefacts.

5.4.3. Physical artefacts modality

For the last artefact modality, participants were shown all six physical artefacts. These artefacts were hidden away under a large cardboard box placed on a rolling table so none of the participants knew they would be seeing the physical artefacts later on during the session. Once the participants were allowed to view the physical artefacts, the table was wheeled over to the participants and the cardboard box was removed from the table. The height of the table was low to ensure that participants sat while viewing the physical artefacts, again to maintain consistency with the previous digital modalities. The artefacts were pre-arranged on the table (see Figure 45). A short description was placed near the corresponding artefact for the participant to read, along with instructions stating not to touch the artefacts. Additionally, there were no reminders that the artefacts belonged to a museum other than comparable instructions stating that participants were not allowed to touch any of the artefacts, the purpose being to simulate the conventional experience of viewing artefacts in a museum. However, they could look at any of them as closely as they liked. The same artefact questionnaire was given to them once they finished viewing the artefacts.

Figure 45. Participant view of the physical artefacts displayed on a table. Top row: bronze bust, gourd, baboon skull; Middle row: necklace, comb; Bottom row: Kora sword.

Following the physical artefact modality, participants were asked to complete the Emotional Intelligence Questionnaire.

Sessions with each participant generally took one hour to complete, with each artefact modality section varying depending on the participant.

As with the preliminary study, all data were kept anonymous and given only a number to associate the consent form, questionnaires, video-recordings, and transcribed sessions to the same participant.

5.5. Pilot testing of study procedure

A pilot test of the procedure was conducted to ensure its validity and to understand the types of comments participants made during each artefact modality. The entire study procedure was carried out using two PhD students from other departments at the University of Kent who had minimal or no prior knowledge about 3D models or AR apps. Afterwards, both sessions were transcribed. The test participants provided interesting and varying responses on the questionnaires. Additionally, they seemed to forget they were being videotaped, and participants responded as expected while interacting with the digital modalities; they felt emotional connections, talked about memories, and constructed meaning based on previous knowledge and their backgrounds.

5.6. Framework to understand how meaning is given to artefacts

To understand how interacting with digital artefacts can lead to emotional connections and meaning, the viewer-artefact interaction needs to be explored as a user-digital artefact interaction. This entails an in-depth analysis of the user's experience as they interact with digital artefacts, and this is best accomplished through narration. Many studies employ the think-aloud method (Charters 2003) to understand what participants are thinking, especially in museum research. There has been past research on understanding participants' comments while viewing museum objects using the think-aloud or similar stream-of-consciousness methods, but the objects used were either works of art such as paintings (Housen 1999), contemporary

art (Émond 2005), science exhibits (Mortensen 2011), or architectural exhibitions (Laberge 2010). The think-aloud method has also been used to understand the user experiences (UX) of participants with no prior knowledge of cultural heritage as they interacted with a digital bank that enabled users to 'acquire, create, and […] reuse digital cultural heritage' (Zahidi, Lim, and Woods 2014; Zahidi, Yan Peng, and Woods 2013). However, the researchers focused on the interface's functions and the users' expectations, motivations, and feelings toward the system, not specifically on the digital artefacts themselves.

5.6.1. Framework by Dufresne-Tassé and Lefebvre

A framework that focuses on museum artefacts and uses the think-aloud method was proposed by Dufresne-Tassé and Lefebvre (1994). The framework analyses the in-situ thought processes of museum visitors when viewing artefacts to study how visitors give meaning to artefacts, and as a result, learn in a museum; this framework also examines cognition and emotion. Dufresne-Tassé and Lefebvre asked participants to verbalise what they see, think, and feel as they visited a museum, and their framework was tested in different types of museums using the constructivist approach. Housen (1999) similarly developed a viewer-object interaction framework based on museum visitors' responses using the think-aloud method, but she focused on understanding the visitor's aesthetic response. Her framework comprised five stages that describe a visitor's mind-set when responding to a work of art, and the stages progress from 'naïve to complex responses'. The framework's stages indicated that people in each stage make sense of the art in different ways. In contrast, Dufresne-Tassé and Lefebvre's framework focused on how visitors gave meaning to museum objects. Additionally, Dufresne-Tassé and Lefebvre utilised the framework to understand visitors to various types of museums, not just fine arts museums, including a natural history museum, a museum of history and ethnology, and a museum of natural sciences. It is for these reasons that Dufresne-Tassé and Lefebvre' framework was considered for this study.

This framework has been recently used to understand visitors' experiences to two types of museums not examined in Dufresne-Tassé and Lefebvre's (1994) research. Laberge (2010) evaluated architects' and non-architects' verbal responses as they

visited architectural exhibitions, which can be complex but usually involve displays of a limited number of objects. Her aim was to identify how visitors' interact with architectural exhibitions and the engaging aspects of an exhibit. Dufresne-Tassé and Lefebvre's framework enabled Laberge to analyse visitors' experiences and identify the exhibitions that were most popular for architects and non-architects. Laberge determined that visitors who had a lot to say used the most mental operations, and both the architects and non-architects were most engaged with the display that had photographs, as evidenced by the number of mental operations used. The framework also confirmed that the display with the largest difference in mental operations used between the architects and non-architects involved architecture plans, which were complicated and difficult to read. Dufresne-Tassé and Lefebvre's methodology has also been referred to when evaluating visitors' experiences at a science museum (Mortensen 2011). Mortensen found that it was an effective method of gaining 'an objective reflection of informant thought processes'. As a result of her study, she recommended that modifying an exhibit's design and engaging visitors' imaginations could improve visitors' learning in the museum.

Dufresne-Tassé and Lefebvre's framework has yet to be applied to the experience of viewing digital museum artefacts. Whether visitors view artefacts in person or online, they still see, think, and feel, the same activities that Dufresne-Tassé and Lefebvre asked their participants to verbally discuss as they looked at artefacts. Additionally, Dufresne-Tassé and Lefebvre found that there were no significant differences in the production of mental operations and age when visitors viewed artefacts from a physical museum. However, they focused on participants with a diverse age range, and if users access digital artefacts using different technologies, the modality and users' diverse experiences with technology might affect their mental operation production, and therefore, their artefact experience (see section 2.3.2). While Laberge used the framework to compare architects and non-architects, so far, it has not been used to compare experiences of older and younger adults, two age groups with traditionally diverse technology backgrounds (see section 2.1.3). Due to these reasons, this study will utilise Dufresne-Tassé and Lefebvre's framework to analyse older and younger adults' experiences of viewing and interacting with digital artefacts.

5.6.2. Structure of Dufresne-Tassé and Lefebvre's framework

Dufresne-Tassé and Lefebvre developed their framework by first gathering data from a total of 135 visitors, 45 of whom visited a natural history museum and 90 who visited a fine arts museum, a museum of history and ethnology, or a museum of natural sciences. Visitors' remarks during the visit were transcribed and analysed, which resulted in four different aspects of a visit: 1) Mental operations; 2) Orientation of visitor's psychic activity; 3) Direction of attention; and 4) Form of operation.

5.6.2.1. Mental operations

Dufresne-Tassé and Lefebvre found that their participants performed 12 mental operations during their museum visits (see Table 3). While they described how and where they gathered their data in order to develop the framework, they did not explain in detail the definitions they used for each mental operation (Dufresne-Tassé and Lefebvre 1994). Table 3 lists the few examples provided by them. Therefore, in order to define all the mental operations, past studies that reference the mental operations were considered, in addition to email communication with the first listed author, Dufresne-Tassé. She was contacted for assistance with a more detailed explanation of the mental operations and responded by sending a text in French that included examples of the mental operations (Dufresne-Tassé 2014); this section was translated by a native French speaker. The examples can be seen in Table 3.

Mental Operation	Examples
Expressing	“Well that's ugly!”
Taking Note of	“I am aware that it is a mollusc.”* “I am aware that I like it.” * "Look, that is a thorn shell."* "Look, that is the shell from which purple was extracted in ancient times."* “Oh yes, that’s right, it takes place in 1608.”
Identifying	“This is a map from the 18th century.”
Evoking	“That house in the painting, it makes me think of the one where we spent our holidays when I was a child.”
Anticipating	“Probably there, we'll see maps not as old.”
Comparing-Distinguishing	“This one is as beautiful as that one. Here it is gray when there it is black.”
Grasping	“Oh, I understand how orchids grow.”
Explaining-Justifying	“It is because the artist has put these two colors next to the other that it vibrates when you look for a long time.”
Situating	“[Krieghoff painted several subjects] Indians, inn parties, landscapes, comic scenes.”
Verifying	“‘Is this really an old pump?’ The visitor reads the cartel and says, ‘It is a pump.’”
Judging	“What they are saying here is not correct because there had been maps where North was not always up.”
Solving-Modifying-Suggesting	Modifying: “[I thought this painting was from Suzor-Côté.] No, it's Clarence Gagnon.” Suggesting: “I would put small objects much closer.” Solving: “Ultimately, this is an instrument that was helpful, but was complicated.”

* Examples from Dufresne-Tassé and Lefebvre (1994)

Table 3. Examples of mental operations provided by Dufresne-Tassé (2014)

5.6.2.2. Grouping categories

Dufresne-Tassé and Lefebvre grouped the mental operations to help to put them into context (see Table 4). *Getting Acquainted with Objects* involves *Expressing*, *Taking Note of*, and *Identifying*; it usually occurs when first encountering an object. *Evoking*, *Anticipating*, *Comparing-Distinguishing*, *Grasping*, and *Explaining-Justifying* all relate to *Building on What Has Been Seen*, and comments are either based on other objects in the museum or a viewer's previous experiences. *Controlling Production* includes *Situating*, *Verifying*, and *Judging*. Based on Dufresne-Tassé's examples, *Controlling Production* is the way visitors analytically take control over aspects of artefacts that they have knowledge about or can check. *Improving What Has Been Constructed* requires *Solving-Modifying-Suggesting* and includes participants changing previous comments, providing suggestions for a museum's display methods, or implying that artefacts need improvement (Dufresne-Tassé and Lefebvre 1994).

Dufresne-Tassé made minor changes to these mental operations in subsequent publications, for example separating the *Solving* operation from *Modifying-Suggesting* (Dufresne-Tassé 1995). These mental operations have also been referenced in later works by the author (Dufresne-Tassé 2014; O'Neill and Dufresne-Tassé 1997; Dufresne-Tassé 1995). The original 12 mental operations are referenced due to the Dufresne-Tassé and Lefebvre's inclusion of explanations regarding the research conducted and their findings.

Mental Operation	Grouping Category
Expressing	Getting Acquainted with Objects
Taking Note of	Getting Acquainted with Objects
Identifying	Getting Acquainted with Objects
Evoking	Building on What Has Been Seen
Anticipating	Building on What Has Been Seen
Comparing-Distinguishing	Building on What Has Been Seen
Grasping	Building on What Has Been Seen
Explaining-Justifying	Building on What Has Been Seen
Situating	Controlling Production
Verifying	Controlling Production
Judging	Controlling Production
Solving-Modifying-Suggesting	Improving What Has Been Constructed

Table 4. 12 mental operations and their grouping categories by Dufresne-Tassé and Lefebvre (1994)

5.6.2.3. Orientation

The orientation of visitor's psychic activity can be either *Cognitive*, *Affective*, or *Imaginative*. Dufresne-Tassé (1995) determined that for adults, it was the cognitive and affective experience, not learning, which was the 'most obvious benefit of a visit to the museum'. The orientation was initially defined to be *Cognitive* or *Affective*. Imagination was said to be part of the Cognitive orientation (Dufresne-Tassé and Lefebvre 1994) but has since been described as its own separate orientation (Dufresne-Tassé 2011). Dufresne-Tassé and Lefebvre highlighted the difference between the *Cognitive* and *Affective* orientations using the *Taking Note of* mental operation in the following examples: "I am aware that it is a mollusc" is *Cognitive*, while "I am aware that I like it" is *Affective* (Dufresne-Tassé and Lefebvre 1994). The orientations were referred to as *Cognition*, *Emotion*, and *Imagination* when Fairchild (1991) associated them with the 12 mental operations. As Table 5 shows, not every orientation is experienced in each mental operation. Fairchild was one of Dufresne-Tassé's collaborators in publications written in French that referred to the mental operations (Dufresne-Tassé et al. 1998a, 1998b) and therefore has extensive knowledge on this topic. She defined *Cognition* as using logic and rational thinking,

Emotion as using feelings, and *Imagination* as using invention, memories, and fantasy (Fairchild 1991).

Mental Operation	**Orientation**		
	Cognition	**Emotion**	**Imagination**
Expressing		✓	✓
Taking Note of	✓	✓	✓
Identifying	✓		
Evoking	✓	✓	✓
Anticipating	✓	✓	✓
Comparing-Distinguishing	✓	✓	✓
Grasping	✓	✓	✓
Explaining-Justifying	✓	✓	✓
Situating	✓		✓
Verifying	✓		✓
Judging	✓		✓
Solving-Modifying-Suggesting	✓	✓	

Table 5. 12 mental operations associated with their potential orientations by Fairchild (1991)

Based on Fairchild's associations, the three mental operations that form C*ontrolling Production* (*Situating*, *Verifying*, *Judging*) do not involve the use of emotions. In contrast, the comments in *Improving What Has Been Constructed*, which only contain the mental operation *Solving-Modifying-Suggesting*, are not only critical, but emotional. Later, Dufresne-Tassé et al. (1998b) stated six possible combinations for the orientation, with *Imagination* never experienced on its own: 1) *Cognitive*; 2) *Affective*; 3) *Cognitive* and *Affective*; 4) *Cognitive* and *Imagination*; 5) *Affective* and *Imagination*; 6) *Cognitive*, *Affective*, and *Imagination*. These combinations further clarified Fairchild's assessment, making it clear that although Fairchild does not

specify that *Cognition* or *Emotion* can be experienced by itself, it is possible to only experience one orientation. To maintain consistency with the terms mentioned beforehand and for the rest of the thesis, the orientations will be referred to as *Cognition*, *Emotion*, and *Imagination*, as listed by Fairchild (1991).

5.6.2.4. Direction of attention and form of operation

The last two aspects of Dufresne-Tassé and Lefebvre's framework are less detailed than the previous two, as they are more self-explanatory. Direction of attention states the possible people or objects that a visitor can direct their attention to in a museum. They include the object observed, other objects, labels, other situations, the visitors themselves, and other visitors. The form of operation is related to the types of comments visitors make and includes questions, hypotheses, actions, learning, hesitation, and exclamations (Dufresne-Tassé and Lefebvre 1994). This aspect is considered additional information to the other three aspects and is not limited to the types listed (Dufresne-Tassé 1995).

This section indicates that more understanding is needed concerning emotional responses to first seeing the digital artefacts, especially when the viewers do not have any cultural connections to the artefacts. While there has been research comparing emotional responses to digital and physical museum objects, as well as emotional responses to digital artefacts viewed online by participants outside a museum, the way older and younger people emotionally respond to first viewing the digital artefacts, then the physical artefacts, outside a museum using different types of digital modalities, has received less attention. In addition, although there are methods for understanding how meaning is given to artefacts through the viewer-object interaction, more knowledge is needed about the user-interactive 3D artefact interaction, especially when it takes place outside a museum, the users are older and younger adults, and the digital artefacts are seen before the physical museum artefacts.

5.7. Conclusion

This chapter detailed the methodologies for the main study of this thesis, including how participants were selected, data collection methods, the procedure for each participant session, and the specifics of the digital and physical artefact modalities.

The next chapter presents the quantitative analysis of data based on the time spent with artefacts in each modality and the artefact questionnaires. The results will provide insight into participants' emotional responses to artefacts when interacting with the digital modalities and how this affected their subsequent emotional experience of viewing the physical artefacts.

Chapter 6: Emotional Connections with Digital Artefacts on Personal Devices

The previous chapter discussed the procedure for collecting data from older and younger participants. Participants spent time interacting with artefacts, then completed questionnaires to indicate any emotional responses they felt while interacting with the digital, then physical, artefacts. Previous studies that discussed emotional responses in their investigations of viewer responses to museum collections concentrated on comparing art-trained and non-trained participants' responses to digital and original artworks (Locher, Smith, and Smith 2001), exploring the responses of students situated in the same location where the digitised artefact originated (Hogsden and Poulter 2012b), or classifying digital and physical artwork according to a broad range of participants or users (Bertola and Patti 2013; Taylor 2001). Moreover, most of these studies focused on participant responses to objects in one modality type, and these modalities did not necessitate any interaction with devices. As online digital artefacts are accessed using devices that require some technology skills, more research is needed to understand how older and younger adults, two groups with disparate technology backgrounds, emotionally respond to digital cultural heritage artefacts.

Museum objects can trigger different types of reactions; some enable visitors to remember the past and make connections, others remind visitors of people, places, or information read in books or viewed in films. Perhaps it might not even be the whole object itself, but specific aspects such as its colour, shape, or texture that connote a personal meaning. When visitors make their own personal connections to artefacts, it can lead to feeling emotions, an important aspect of the museum experience (see section 2.4). Many artefacts cannot be removed from a museum, and there may be an audience who are physically unable to visit them in person. Additionally, some artefacts are exhibited behind glass cases or displayed in such a way that not all angles and features can be viewed. When these artefacts are digitised and made available online, they can be accessed by anyone at any point in time, which can lead to the unique situation of seeing the digital artefact before the physical one. Therefore, museum artefacts could benefit from digital representations, but there

needs to be a greater understanding of how users engage with and emotionally respond to 3D artefacts viewed on different devices before they have seen the physical artefacts. This can have significant effects, including influencing a user to visit a museum, spend more time on a museum's website, or revisit the website in the future. Additionally, when technology is needed to access and interact with artefacts, as in personal devices, the users may have different skills that can affect their responses.

In this chapter, the potential of the 3D models on a laptop and AR on a tablet modalities for enabling emotional connections will be explored quantitatively. Focus is placed on participants' responses to the questionnaires and their time spent in each modality, which was gathered through the video recordings.

Based on the review of past research, more understanding is needed regarding the emotional responses of older and younger adults to digitised cultural heritage artefacts when first viewed outside of a museum. Additionally, exploring how these responses affect the physical artefact experience using the same participants requires further attention. As such, the aims of this chapter are as follows:

1) Investigate whether interaction with digital artefacts outside of a museum can lead to emotional responses from older and younger adults
2) Determine whether older and younger adults are more emotionally connected to 3D artefacts on a website or an AR app
3) Investigate the emotional responses of older and younger adults when viewing the physical artefacts after the digital artefacts

6.1. Data Analysis

This study endeavoured to achieve these aims by assessing how older and younger participants engage with artefacts in all three modalities, the 3D models on a laptop, AR on a tablet, and physical artefacts, and evaluating their emotional reactions to these artefacts in each modality. The motivation for choosing to show the 3D artefacts on a website using a laptop and an AR app on a tablet is discussed in section 2.2. Explanations about the creation of the 3D models, website, and AR app can be

found in Chapter 4. As this was a within-subjects study, participants were asked to verbalise and explain their actions, thoughts, feelings, associations, or memories as they viewed and interacted with the artefacts in all three artefact modalities. Using counterbalancing, participants first viewed the two digital modalities, either the AR on a tablet or 3D models on a laptop. The physical artefacts modality was shown last for all participants. The full methodology is discussed in Chapter 5.

The results were analysed using IBM SPSS Statistics Version 19 to explore the links between artefact modality and age. All sessions were transcribed and the amount of time participants spent with each artefact in the modalities was timed based on the video recordings, resulting in each participant having three totals representing the time spent in each of the three modalities. The questionnaires also provided data that were analysed in this chapter, including rankings of enjoyment and emotional responses. Several of these variables, particularly time spent within each modality and the emotional responses, needed to be standardised or converted to quantifiable numbers.

6.1.1. Time spent within each modality

First, the time spent within each modality was measured. Here, time spent included only the actual amount of time spent with artefacts; if a participant took time to become familiar with the technology at the beginning, that time was not counted. Since participants' devices were facing away from the video camera and the artefacts they were looking at could not be seen when they were using the digital modalities, they were asked to verbalise what artefact they were interacting with and when they were finished in both digital modalities for consistency. The official start time was based on the method of Tillon, Marchal, and Houlier (2011), who measured the time participants spent on both an AR guide and artworks starting from when they stopped in front of the artwork. Therefore, the start time for each artefact was when participants stated what artefact they were looking at. As such, the official end time for an artefact interaction was when a participant started talking about the next artefact, or, if they reached the last artefact, when they stopped talking. The time was calculated based on the displayed time on the video player while the video recordings were watched.

The time spent with artefacts first had to be processed before any analysis could be done. The older participants typically spent more time speaking about artefacts compared to the younger participants, and as a result, the time spent with the AR on a tablet, 3D models on a laptop, and physical artefacts had to be standardised to ensure that all of the values were in proportion with one another. First, the values for the times were changed from a combination of minutes and seconds to just seconds, leaving each participant with three time values for each modality. Second, to get the proportion of time spent in each artefact modality, the total number of seconds spent in each modality was divided by the cumulative total. After the conversion, the values for how long each participant spent with artefacts in each modality were between 0 and 1. By converting the times spent in the three modalities into a proportion of their total interaction time, all participants' data could be compared uniformly.

6.1.2. Emotional responses

Questionnaire answers concerning emotional responses to the artefacts were converted to a quantifiable measure. First, the number of basic emotions was counted and given a total number within each modality. In addition, the emotions listed as *Other* were assessed and counted. Since *Interest* was mentioned by a quarter of the participants**,** it was included as an emotion. In total, each participant had three emotion counts: one for the AR on a tablet, one for the 3D models on a laptop, and one for the physical artefacts. Furthermore, the emotions were given a value for their valence and arousal, concepts that were applied to emotions in a circular spatial model by Russell (1980). Valence defined how pleasant or unpleasant an emotion was, while arousal represented the intensity of the emotion.

In order to associate a value to an emotion's valence and arousal, the Circumplex Affect Assessment Tool (CAAT) was used (Cardoso, Romão, and Correia 2013). This approach was chosen due to its inclusion of Ekman's six basic emotions (see section 5.3.4) as well as *Interest* and *No Emotion*, the latter of which will be referred to as *Indifferent* to maintain consistency with the emotions listed in the questionnaires. It also organised emotions based on Plutchik's (2001) three-dimensional Circumplex Model of Affect (see Appendix J), which expanded on

Russell's model by organising emotions similar to a colour wheel, with opposite emotions located across from each other and comparable emotions located adjacent to one another. In CAAT, each emotion has a value ranging from 1 (low) to 7 (high), based on 7 linear 'containers' arranged within the circular spatial model. Using these values, a scoring system calculated the S_1 score, which represented the combined valence and dominance (the degree of being in control as opposed to being controlled by a stimulus) scores, and S_2 score, which was the arousal score (see Table 6). Though their system combined valence and dominance, the S_1 score in CAAT is largely guided by valence.

When participants stated that they felt these emotions to the artefacts on the questionnaires, the emotions were given the corresponding S_1 and S_2 scores. If participants listed two or more emotions within each modality, the S_1 and S_2 values were calculated by averaging their values. Again, each participant had three sets of S_1 and S_2 scores: one for the AR on a tablet, one for the 3D models on a laptop, and one for the physical artefacts.

Emotion	**S_1**	**S_2**
Anger	3.3	6
Disgust	2.3	5
Fear	2	6
Happy *	6	6
Sad	2	2
Surprise	3.3	6
Interest	4.7	5
Indifferent	0	0

* Referred to as Joy in CAAT

Table 6. CAAT scoring system

6.2. Results

6.2.1. Participant museum and technology background

All participants completed a demographic questionnaire at the beginning of the session; this requested information about mobile device experience, their familiarity with 3D virtual objects, familiarity with AR, frequency of museum visits in the past 12 months as well as frequency of viewing museums' collections online in the past 12 months (see Appendix G). Table 7 summarises these results, which show that in general, the participants were not that familiar with 3D and even less familiar with AR. Older people visited a museum more frequently than younger people in the last 12 months. The mean for the number of visits to museums' online collections in the past 12 months was about the same for all participants.

	Older (65+)		**Younger (18-21)**	
	M	**SD**	**M**	**SD**
Age	71.3	4.612	19.4	0.995
Experience using a smartphone or tablet?				
Yes	0.55	0.510	1	0
Familiarity with 3D Rating (0= Never Heard of It, 5= Very Familiar)	2.15	1.599	2.55	1.191
Familiarity with AR Rating (0= Never Heard of It, 5= Very Familiar)	0.65	1.089	1.55	1.504
Number of Museum Visits (Past 12 Months)	4.15	1.387	1.90	1.210
Number of Online Museum Visits (Past 12 Months)	1.20	1.609	1.45	1.504

* M = mean; SD = standard deviation

Table 7. Participant technology and museum background

All younger participants had experience with mobile devices compared to about half of the older participants. The independent *t*-test showed that younger participants

had significantly different mobile device experience compared to the older group, $t(38) = 3.943$, $p < 0.001$, $r = 0.54$, which is in line with past research comparing older and younger people and technology usage (Olson et al. 2011).

The Demographic Questionnaire asked participants to rank their familiarity with 3D models and their familiarity with AR on a scale from 0 (Never Heard of It) to 5 (Very Familiar). The independent *t*-test showed that the older and younger participants had no significant difference in their familiarity with 3D models, $t(38) = 0.897$, $p = 0.375$, $r = 0.14$. However, the younger group had a significantly higher familiarity with AR than the older group, $t(38) = 2.168$, $p < 0.05$, $r = 0.33$.

Between the 20 older and 20 younger participants, the older group had a higher number of museum visits in the past 12 months. The independent *t*-test showed that the older group visited museums a significantly higher number of times than the younger group, $t(38) = -5.468$, $p < 0.001$, $r = 0.66$, which follows current museum reports (NEA 2015). Participants were also asked to state the number of times they went online to view a museum's collections within the past 12 months. There was no significant difference between older and younger participants, $t(38) = 0.508$, $p = 0.615$, $r = 0.08$.

6.2.2. Emotional Intelligence score

At the end of each session, all participants completed an Emotional Intelligence questionnaire. The independent *t*-test showed that there was no significant difference between older (121.33 ± 12.274) and younger people's (118.75 ± 12.624) Emotional Intelligence Scores, $t(38) = -0.654$, $p = 0.517$, $r = 0.11$.

6.2.3. Overview of variables in each modality

In the following subsections, differences between older and younger participants in the three modalities of artefact presentation, AR on a tablet, 3D models on a laptop, and physical artefacts, will be discussed in relation to the following dependent variables: 1) time spent in each modality; 2) ranking of modality; 3) emotion count; 4) S_1 and S_2 values.

Figure 46 provides a summary of the average time participants spent with artefacts in each modality. The graph shows that both age groups spent a comparable amount of time in the two digital modalities and the least amount of time in the last modality with the physical artefacts. The remaining variables and their comparisons by modality and age are presented in Figure 47. With regards to their enjoyment of the modalities, the older participants found the physical artefacts the most enjoyable, which was to be expected based on general differences between these age groups and their museum opinions and technology knowledge (see section 2.1), while the younger group ranked all three modalities similarly. Nevertheless, both age groups ranked the modalities fairly highly, at least a 7 out of 10. Their emotion counts and S_1 and S_2 scores were fairly similar in each of the three modalities. This indicates that although they may have a difference of opinion as to the modality they enjoyed the most, each modality enabled them to experience a similar number of emotions and levels of valence, dominance, and arousal.

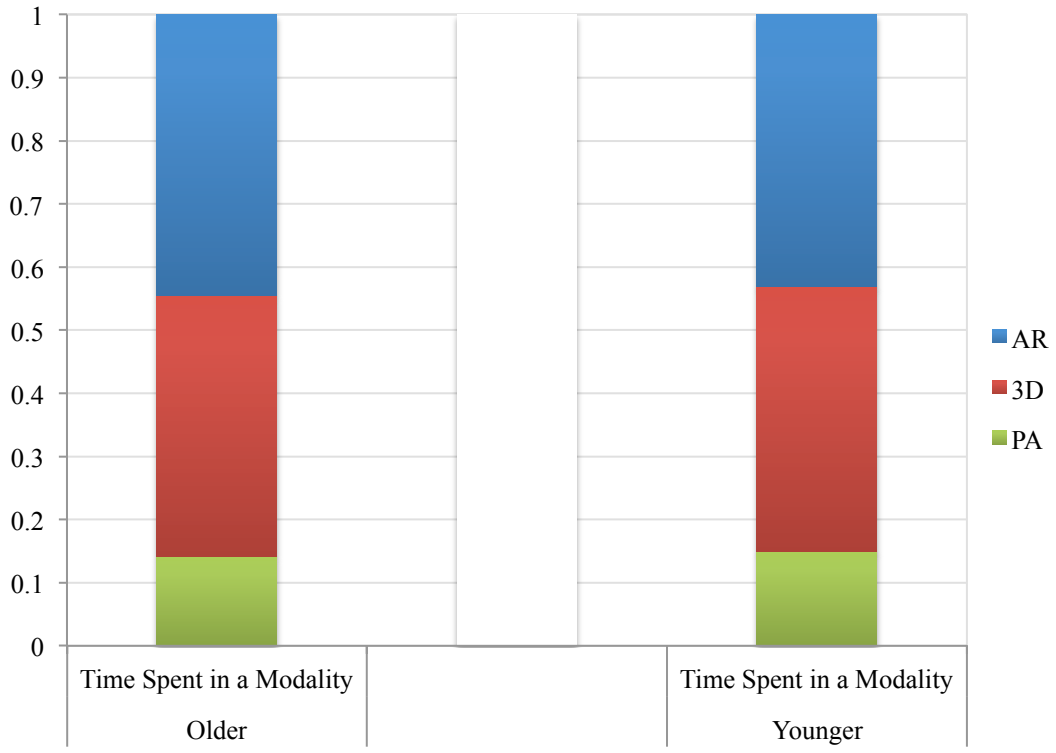


Figure 46. Time spent within each modality by age

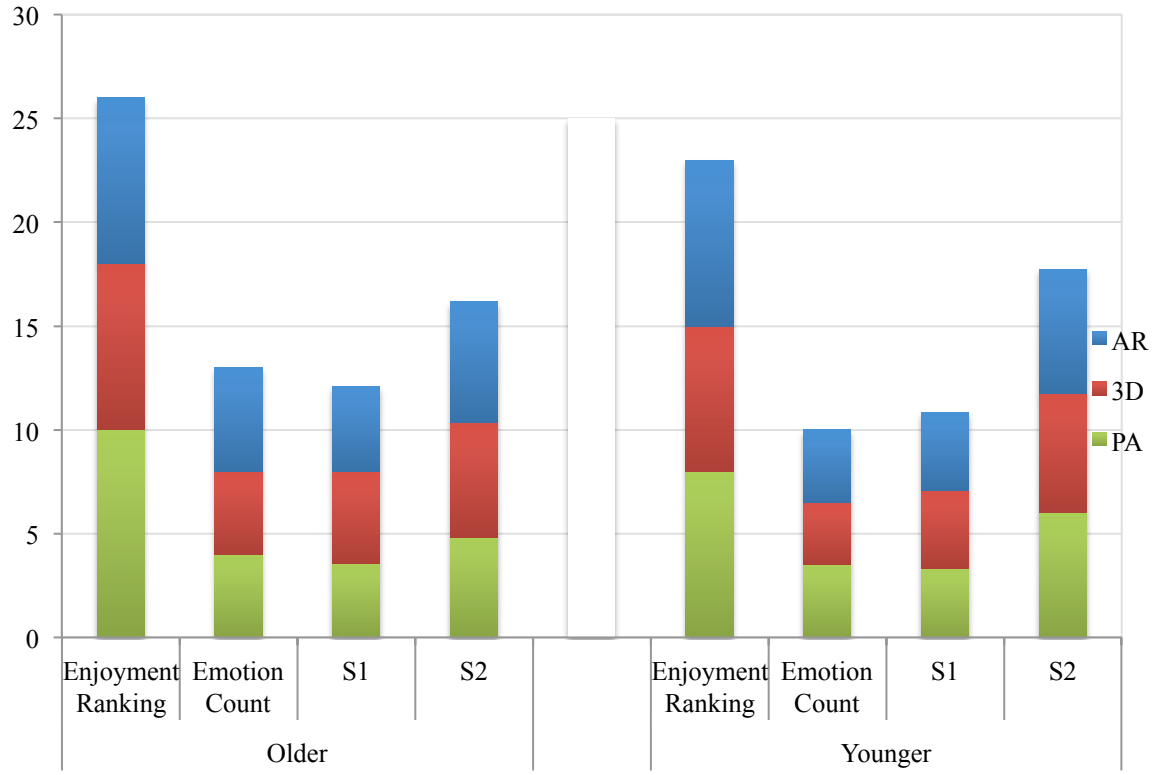


Figure 47. Enjoyment, emotion counts, and S_1 and S_2 scores within each modality by age

6.2.4. Statistical analysis of modality comparisons

To understand the links between the modalities, age, and emotional responses, the four dependent variables will be analysed using SPSS.

6.2.4.1. Time spent within each modality

To gain insight about how engaged the participants were, the time spent in each modality was analysed. Analysing the length of time spent at exhibitions, displays, and installations in museums provides a way to understand the visitor experience and has been done since the early part of the 20th century (Bitgood, McKerchar, and Dukes 2013; Yalowitz and Bronnenkant 2009; Melton 1935).

As a whole, all 40 participants spent the most time with the AR on a tablet modality with a mean of 0.438 ± 0.095. Second was the modality with the 3D models on the

laptop, which had a mean of 0.417 ± 0.099. Third was the physical artefacts modality, with a mean value of 0.146 ± 0.061. A one-way repeated-measures ANOVA test was used to discover if any of the artefact modalities influenced how long a participant interacted with an artefact. This determined that the change from a digital modality to the physical artefacts modality led to a significant decrease in the time spent with the artefacts ($F(1.590, 62.028) = 94.604$, $p = < 0.0005$, $\omega^2 = 0.701$). This was not surprising since participants had already seen the artefacts in two digital modalities, and these were novel methods of interacting with museum artefacts, as their questionnaire results indicated (see section 6.2.1). *Post hoc* tests using the Bonferroni correction showed that participants spent more time viewing and interacting with the AR on a tablet than viewing the physical artefacts (0.438 ± 0.095 vs. 0.146 ± 0.061), which was statistically significant ($p < 0.0005$). Also, they spent more time viewing and interacting with artefacts in the 3D models on a laptop modality than viewing the physical artefacts (0.417 ± 0.099 vs. 0.146 ± 0.061), which was also significant ($p < 0.0005$). Furthermore, the time participants spent interacting with the AR on a tablet modality was not significantly different than the time spent with the 3D models on a laptop.

Comparing older and younger participants (see Table 8), an independent *t*-test showed that there was no significant difference between them and the time spent in the AR on a tablet modality ($t(38) = -0.445$, $p = 0.659$, $r = 0.072$), the 3D models on a laptop modality ($t(38) = 0.207$, $p = 0.837$, $r = 0.034$), or the physical artefacts modality ($t(38) = 0.359$, $p = 0.721$, $r = 0.058$).

6.2.4.2. Ranking of enjoyment

As engagement with museum activities, collections, and technology has been linked to well-being, participation, and meaningful experiences (see section 2.1), the enjoyment of each modality was also analysed. After each of the three modalities, participants ranked their enjoyment of the artefacts on a scale of 1-10, with 10 being the highest enjoyment.

		Older (65+)		Younger (18-21)	
		M	**SD**	**M**	**SD**
Time Spent with Artefacts (proportion of time spent)	**AR**	0.445	0.115	0.431	0.072
	3D	0.413	0.113	0.420	0.084
	PA	0.142	0.075	0.149	0.044
		Mdn	**IQR**	**Mdn**	**IQR**
Ranking of Enjoyment (on a scale from 1= Low to 10 = High)	**AR**	8	3	8	1
	3D	8	3	7	2
	PA	10	1	8	2

AR = AR on a tablet modality; 3D = 3D models on a laptop modality; PA = physical artefacts modality; M = mean; SD = standard deviation; Mdn = median; IQR = Interquartile range

Table 8. Differences in age for time spent and ranking in each artefact modality

Among all participants, the physical artefacts modality was enjoyed the most with a median of 9.00 and an Interquartile range (IQR) of 3. Next were the digital modalities, with the 3D models on a laptop having a median of 8.00 and an IQR of 3 and the AR on a tablet with a median of 8.00 and an IQR of 1. Due to this ranking data violating some of the assumptions required to run the parametric tests, non-parametric tests were run. Unlike with the one-way repeated-measures ANOVA test, the Friedman's ANOVA test, the corresponding non-parametric test in SPSS, did not allow testing for between-subject factors at the same time as the repeated-measures test, which consequently mandated the use of two separate tests for modality and age. As it was important to highlight the differences not only in age, but in modality, the Friedman's ANOVA test was run alongside the Mann-Whitney test. This combination of non-parametric tests was similarly used to evaluate time spent at three different modalities using two different learning programmes in a science museum (Lindgren-Streicher and Reich 2007), which corresponds to the three artefact modalities and two age groups assessed in this main study. For consistency with the non-parametric tests, an independent *t*-test was run alongside the one-way repeated-measures ANOVA test for the time spent within each modality variable, instead of testing for between-subject factors at the same time as the repeated-measures test.

First, Friedman's ANOVA test was run to compare rankings of participants in all three modalities. The results show that the change in modality type significantly affected the ranking, $\chi^2(2) = 20.217$, $p < 0.0005$. Pair-wise comparisons were further analysed using the *post hoc* test called the Wilcoxon signed-rank test. Since three modalities were used, the critical level of significance is $p = 0.05/3$, which equals 0.0167. The results indicated that the ranking was significantly higher for the AR on a tablet modality when compared to the 3D models on a laptop modality, $T = 102$, $p < 0.0167$, $r = -0.40$. It was also significantly higher for the physical artefacts modality when compared to the 3D models on a laptop modality, $T = 9$, $p < 0.0005$, $r = -0.72$. Therefore, in general, participants enjoyed the AR on a tablet modality more than the 3D models on a laptop modality, and their enjoyment increased from the digital modalities to the physical artefact modality.

Observing age differences (see Table 8), the Mann-Whitney test was run to compare the mean rank of participant rankings between older and younger participants in each modality. These two groups had a significant difference in their ranking of the physical artefacts modality, with the older group ranking them higher, $U = 88.00$, $p < 0.005$, $r = -0.50$. The two age groups ranked the digital modalities similarly and therefore, there was no significant difference between them in the AR on a tablet modality ($U = 186.00$, $p = 0.709$, $r = -0.06$) and the 3D models on a laptop modality ($U = 143.00$ $p = 0.121$, $r = -0.25$).

6.2.4.3. Emotional responses

In order to understand if digital artefacts and physical artefacts viewed outside a museum can encourage emotional connections, different variables of emotional responses were analysed. Previous studies stated that a museum's environment may have influenced emotional responses to artworks and objects (Gadsby 2011; Locher, Smith, and Smith 2001; Taylor 2001). In addition, emotional responses are considered the most important part of understanding museum objects (Taylor 2009). Therefore, it becomes important to identify if digital artefacts and physical artefacts viewed outside a physical museum can similarly lead to emotions.

6.2.4.3.1. Emotion count

After each modality, participants listed the emotions they felt on questionnaires. Only the six basic emotions, *Anger, Disgust, Fear, Happy, Sad,* and *Surprise*, plus *Interest*, were counted. Each modality had six artefacts; therefore if a participant felt *Happy* in response to seeing each artefact, the total emotion count was six. The aim was for each artefact, which represented a different category based on the findings of the preliminary study in Chapter 3, to elicit at least one emotion for a total of six emotions in each modality, which would show that the digital or physical artefact was able to influence an emotional response. Many participants listed at least one emotion in response to an artefact and some listed two, with four emotions for one artefact being the most listed by one participant. The results show that participants indeed felt emotions in response to the artefacts in each modality. The AR on a tablet modality had the highest number of emotions with a median of 4.00 and an IQR of 4. Next were the 3D models on a laptop modality with a median of 3.00 and an IQR of 2 and the physical artefacts modality with a median of 3.00 and an IQR of 3. Friedman's ANOVA test was run to compare the participants in all three modalities. The results show that the change in modality type did not significantly affect emotion counts, $\chi^2(2) = 4.436$, $p = 0.111$, therefore, no *post hoc* tests were run.

Observing the differences between the older and younger participants (see Table 9), the Mann-Whitney test showed that these two groups did not differ significantly in the AR on a tablet modality ($U = 153.00$, $p = 0.201$, $r = -0.20$), the 3D models on a laptop modality ($U = 146.00$, $p = 0.141$, $r = -0.23$), or the physical artefacts modality ($U = 191.00$, $p = 0.813$, $r = -0.04$). In general, age did not affect the number of emotions participants felt in response to the artefacts in each modality.

		Older (65+)		Younger (18-21)	
		Mdn	**IQR**	**Mdn**	**IQR**
Emotion Count	**AR**	5	3	3.5	4
	3D	4	3	3	3
	PA	4	5	3.5	4
S_1 (on a scale from 1= Unpleasant to 7 = Pleasant)	**AR**	4.1	1.88	3.77	1.34
	3D	4.44	1.83	3.77	1.24
	PA	3.55	1.19	3.31	1.34
S_2 (on a scale from 1= Low arousal to 7 = High arousal)	**AR**	5.84	0.88	6	0.75
	3D	5.5	2	5.75	1
	PA	4.84	1.83	6	0.83

AR = AR on a tablet modality; 3D = 3D models on a laptop modality; PA = physical artefacts modality; M = mean; SD = standard deviation; Mdn = median; IQR = Interquartile range

Table 9. Differences in age for emotion data in each artefact modality

6.2.4.3.2. Valence, dominance and arousal scores

The S_1 and S_2 scores were calculated for the emotions listed in each modality. The S_1 score represented the combined valence and dominance score and ranged from 1 (unpleasant) to 7 (pleasant). The S_2 score was the arousal score and also ranged from 1 (low arousal) to 7 (high arousal). Out of the seven emotions that were focused on, three had a valence/dominance score of under 3 (*Fear, Disgust, Sadness*), two had a score of 3.3 (*Anger*, *Surprise*), and two had scores over 4 (*Happy, Interest*). All seven emotions had an arousal score of at least 4, except for *Surprise*, with a score of 2 (see Table 6 on page 136). Overall, the valence, dominance, and arousal scores were highest for the AR on a tablet modality, which shows that it was in this modality that the participants felt more pleasant, intense emotions. The median value S_1 score was 4.14 and an IQR of 1.32 and the median value S_2 score was 6.00 and an IQR of 0.66. Second was the median value S_1 score for the 3D models on a laptop modality at 3.99 and an IQR of 1.37 while the S_2 score was the second highest for the physical artefact modality with a median value of 5.88 and an IQR of 1. Third was the S_1 score for the physical artefact modality with a median value of 3.65 and an IQR of 1.10 while the third S_2 score was for the 3D models on a laptop modality with a median value of 5.42 and an IQR of 1. These values show that

participants felt pleasant emotions in the 3D models on a laptop modality but these emotions were not as intense as in the AR modality. In the physical artefacts modality, participants felt less pleasant emotions but they were about the same intensity as the 3D models on a laptop modality. Friedman's ANOVA test was run to compare the S_1 and S_2 scores of participants in all three modalities. The results show that the change in modality type did not significantly affect the S_1 scores, $\chi^2(2) = 4.436$, $p = 0.111$ or S_2 scores, $\chi^2(2) = 4.353$, $p = 0.114$, and no *post hoc* tests were run.

With respect to age differences and S_1 score (see Table 9), the results of the Mann-Whitney test showed that the older and younger participants did not differ significantly in the AR on a tablet modality ($U = 185.00$, $p = 0.691$, $r = -0.06$), the 3D models on a laptop modality ($U = 162.50$, $p = 0.313$, $r = -0.16$), or the physical artefacts modality ($U = 186.00$, $p = 0.712$, $r = -0.06$). Therefore, the artefacts in each modality encouraged emotions with about the same valence regardless of age.

For the S_2 scores (see Table 9), the results of the Mann-Whitney test showed that the older and younger participants did not differ significantly in the AR on a tablet modality ($U = 161.50$, $p = 0.249$, $r = -0.19$), the 3D models on a laptop modality ($U = 174.50$, $p = 0.475$, $r = -0.11$), or the physical artefacts modality ($U = 139.00$, $p = 0.078$, $r = -0.28$). This shows that the artefacts in each modality led to emotions with about the same intensities regardless of age

6.2.5. Summary of findings

- There was a significant decrease in time spent with the physical artefacts compared to the two digital modalities, yet there was no significant difference between older and younger participants and the time spent in each modality. However, all participants saw the artefacts twice in the digital modalities before viewing the physical artefacts.
- While all participants enjoyed the digital modalities, as indicated by their high rankings, participants enjoyed the AR on a tablet modality more than the 3D models on a laptop modality, and their enjoyment significantly increased

from the digital modalities to the physical artefact modality. Older adults enjoyed the physical artefacts significantly more than the younger adults

- Based on no significant differences between the digital modalities and emotion counts, S_1, and S_2 values, participants felt a comparable number of emotional connections to the artefacts in the digital modalities
- There was no significant difference between older and younger participants and their emotional responses within the digital modalities
- There were no significant differences in the change of modality and the number of emotions felt, valence and intensities of emotions. Hence, participants felt a similar number of emotion counts, S_1, and S_2 values to physical artefacts even though they first viewed the digital artefacts and spent more time interacting with them.

6.3. Conclusion

This chapter explored whether older and younger adults engaged with and emotionally responded to cultural heritage artefacts outside of a museum, first in two digital modalities, 3D models on a website shown on a laptop and an AR app on a tablet, and then lastly in the physical modality. In particular, the focus was on the modality's influence on the following variables: length of time spent with the artefacts, ranking of enjoyment, and emotional responses. Next, further analysis is needed to understand how meaning emerged when participants interacted with digital artefacts and how these connections are associated with emotion.

Chapter 7: Meaning from Interactions with Digital Artefacts on Personal Devices

The previous chapter explored how older and younger adults engaged with and emotionally responded to viewing digital cultural heritage artefacts on personal devices outside of a museum, specifically when seeing the digitised artefacts before the physical artefacts. These results were mainly based on self-reported measures, and further analysis is needed to confirm that emotional connections to digital artefacts were in response to the artefacts themselves, not the modalities. Moreover, similar to the preliminary study described in Chapter 3, there needs to be an understanding of how meaning is constructed from interactions with artefacts in each modality.

As Chapter 2 discussed, research has shown that a museum environment can influence visitors' responses to artefacts (Gadsby 2011; Locher, Smith, and Smith 2001). However, it is the viewer who interprets the object, which can lead to emotional connections and meaning. Pearce (1994b) determined that the meaning of a museum object depends upon the interaction between a viewer and an object. Likewise, Weil (1997) stated that a museum artefact does not have one inherent meaning; rather, it is the visitor who applies meaning to it based on personal connections made through memories, culture, and beliefs. Accordingly, interaction with artefacts is most successful if it results in meaning. This can be applied to 3D models of cultural heritage artefacts since they can also be examined and interacted with, which can lead to meaning. Similar to physical artefacts, these interactions involve viewers' backgrounds as well as the formal elements such as colour, shape, or texture, and presentation of objects.

When a museum's audience consists of people with different backgrounds and experiences, it is likely that they will have differing opinions and interpretations of an artefact. The emergence of virtual museums and the availability of 3D artefacts on museum's websites and downloadable apps increase the likelihood of reaching out to a global audience. Viewers may have to depend on their own past to form personal connections when viewing virtual museums and 3D artefacts outside of a

museum. Although it has been shown that digitised museum artefacts can be engaging and lead to meaningful interactions (Hogsden and Poulter 2012b), it is important to have a greater understanding of how meaning emerges from different age groups when they interact with 3D artefacts.

This chapter builds upon the results in the previous chapter by investigating how participants construct meaning through the comments they make while interacting with artefacts using the digital modalities, and afterwards viewing the physical artefacts. This will also further demonstrate that the emotions were in response to the artefacts themselves. Similar to how an artefact's presentation in a museum environment can influence emotional responses (Gadsby 2011; Locher et al. 2001; Taylor 2001), interacting with artefacts on devices can also be influential, especially if users are not familiar with the technology. While the questionnaires after each modality specifically asked 'which artefact made you feel the following emotions', understanding how participants construct meaning through their cognition and emotion can further highlight the viewer-object interaction. Given that themes explaining museum visitors' emotional experiences with physical cultural heritage artefacts were already observed from the results of the preliminary study discussed in Chapter 3, a thematic analysis was not repeated for this analysis. The themes described in the preliminary study were based on interviews occurring after a museum visit, and the preliminary study did not investigate participants' comments while they were viewing the artefacts. Instead, participants' verbalised comments as they interacted with the digital artefacts will be analysed according to the framework by Dufresne-Tassé and Lefebvre (1994), which was discussed in section 5.6.1. Additionally, many of the themes identified in the preliminary study focused on learning and personal backgrounds. Since Dufresne-Tassé and Lefebvre's framework considers learning 'as a process' instead of an outcome, the use of their framework offers a greater understanding of how participants with different backgrounds construct meaning.

As in the last chapter, differences between older and younger adults will be explored, as well as whether seeing the digital artefacts beforehand affects participants' experiences of seeing the physical artefacts. This analysis focused on qualitative data obtained using the think-aloud method (Charters 2003), which asked the

participants to verbalise what they were thinking while viewing the cultural heritage artefacts in each of the three modalities. In contrast with the quantitative data analysed in the previous chapter, the comments made by participants may provide greater insight into their thoughts while viewing the digital artefacts, which can then be compared to their experience when finally seeing the physical artefacts.

Based on the literature review, further investigation is needed to understand how older and younger adults construct meaning while interacting with digital cultural heritage artefacts. Moreover, there is a need to understand how giving meaning to digital artefacts affects the subsequent viewing of physical artefacts, especially when the 3D artefacts may be more accessible and therefore, more likely to be seen beforehand. As a result, the aims of this analysis are to:

1) Determine whether meaning emerged while participants interacted with digital artefacts
2) Compare how older and younger people gave meaning to artefacts in the two digital modalities
3) Understand how giving meaning to digital artefacts beforehand compares to how meaning is given to the physical artefacts in the subsequent interaction

7.1. Data analysis

The aims of this analysis were accomplished by exploring how participants verbalise their thoughts and feelings while interacting with artefacts using three modalities, AR on a tablet, a website using a laptop, and physical artefacts, and determining how and why meaning is given to artefacts. Chapter 4 describes the creation of the 3D models and their implementations on two modalities and Chapter 5 explains the selection of participants and the procedure to each session.

Each session with the 40 participants was recorded and transcribed, keeping track of the time spent with each artefact in each modality. The transcripts were analysed, in the first instance qualitatively using the software QSR NVivo 10 to categorise the comments made by participants according to Dufresne-Tassé and Lefebvre's

framework, and then quantitatively using IBM SPSS Statistics Version 22 to evaluate the links between each aspect of the framework, age, and the modalities.

7.1.1. Qualitative analysis

As discussed in section 5.6.1, the framework by Dufresne-Tassé and Lefebvre (1994) used the think-aloud method to understand how visitors give meaning to artefacts while viewing them in-situ in different types of museums. The framework contains four different aspects of a museum visit; however, for the purpose of this research, only the first two aspects were analysed: mental operations and orientation. The direction of attention aspect was used to categorise comments according to what a participant was referring to, and actions such as zooming or rotating the artefact would fall under the fourth aspect of the framework, called form of operation. This aspect was also used to filter out comments related to usability and highlight whether a comment was a question, which was necessary for coding the mental operations and is explained in section 7.1.1.4. Furthermore, the mental operations were further analysed according to grouping categories (See Table 4 on page 128).

7.1.1.1. Mental operations

Mental operations help to describe the artefact experience and the methods participants use to process information. This can lead to insight about how participants construct meaning. Additional information on the 12 mental operation and their definitions can be found in section 5.6.2.1.

7.1.1.2. Grouping categories

The mental operations can be grouped according to the reasons they were used, leading to valuable information on participants' artefact experiences. As mentioned in section 5.6.2.2, explanations for what *Getting Acquainted with Objects* and *Building on What Has Been Seen* entail are straightforward. *Controlling Production* is the way visitors analytically take control over aspects of artefacts that they have knowledge about or can check. This does not involve the use of emotions, as identified by Fairchild (1991) when associating the 12 mental operations with the 3

orientations. As section 5.6.2.3 highlighted, the three mental operations that form C*ontrolling Production* (*Situating*, *Verifying*, *Judging*) are all associated with *Cognition* and based on logic and rational thinking. In contrast, the comments in *Improving What Has Been Constructed* are not only critical, but also emotional.

7.1.1.3. Orientation

The orientation classifies the root of the mental operations and consists of a combination of three options, *Cognition, Emotion*, and *Imagination*. Further clarification on their distinctions was discussed in section 5.6.2.3.

7.1.1.4. Implementation of Dufresne-Tassé and Lefebvre's framework

As the framework focused on the mental operations used while viewing artefacts, comments related to the usability of the digital modalities were not analysed. Neither were comments that participants were specifically asked to describe out loud, for example, stating what artefact was currently being looked at. After removing comments concerning usability from the interviews as well as the requested statements by the researcher, the remaining comments, totalling 3,928 sentences, were then parsed and categorised into the 12 mental operations and 3 orientations. The mental operations were also classified into their grouping categories.

Due to the large number of data collected and transcribed, the comments for each artefact were separated into sentences and then coded for mental operations and orientations. A sentence ended once the participants came to a full stop in their comments. If a participant started using one mental operation, then switched to another and came back to the initial mental operation, that mental operation was only counted once along with the other mental operation used. Once an emotion was associated with a mental operation, it did not get counted again if it reappeared in the same sentence. For example, one participant said:

> *"I don't normally spend much time looking at weaponry…this is Nepalese apparently…because I don't really like seeing what they can do but I haven't got a lot to say about this one but I do like looking at the design on swords and knives and things and sometimes they are so intricate and so beautiful, and then you look at what they, how they're used so this one looks particularly nasty with a hook at the end, to really make sure it goes right into or cuts right through a neck I would think."*

This was coded as:

> "I don't normally spend much time looking at weaponry [*Explaining-Justifying/Cognition*]…this is Nepalese apparently [*Taking Note of/Cognition*]…because I don't really like seeing what they can do but I haven't got a lot to say about this one [*Explaining-Justifying/Emotion*] but I do like looking at the design on swords and knives and things and sometimes they are so intricate and so beautiful and then you look at what they, how they're used so this one looks particularly nasty with a hook at the end [*Taking Note of/Emotion, Imagination*], to really make sure it goes right into or cuts right through a neck I would think [*Explaining-Justifying/Cognition, Imagination*]".

Although the participant kept switching from *Explaining-Justifying* and *Taking Note of*, they each were only counted once within a sentence. Likewise, orientations of *Cognition, Emotion*, and *Imagination* were only counted once within that sentence although they appear more than once. Additionally, any questions asked by participants were categorised as either *Identifying, Explaining-Justifying*, or *Verifying* (Dufresne-Tassé, Dao, and Lapointe 1993). As coding was a painstaking task done by one person, this process allowed for quicker analysis as well as reduced the likelihood of coding errors. The coding was checked for reliability by external researchers who read a sample of sentences and coded them according to the framework; the results corresponded to the original coding. Table 10 shows some examples of each mental operation from this research along with their associated orientation(s).

Mental Operation	Examples from this research	Orientation(s)
Expressing	"Oh wow!"	Emotion
	"That looks a bit scary."	Emotion
Taking Note of	"Well, it doesn't seem to have a very sharp blade."	Cognition
	"Those big teeth are really big, scary big."	Cognition, Emotion
Identifying	"So I'm guessing the woman, is an Egyptian queen."	Cognition, Imagination
	"I'm interested in the age of the comb."	Cognition, Emotion
Evoking	"When I was a child I think we must have had some or learned about gourds or something."	Cognition, Imagination
Anticipating	"So this would be quite a heavy sword I would think."	Cognition, Imagination
Comparing-Distinguishing	"The comb is shorter than I expected."	Emotion, Imagination
	"I mean the face is rather serene, like you sometimes see on mummies."	Emotion, Imagination
Grasping	"I don't understand why it's sort of curved like this but it has some special use."	Cognition
Explaining-Justifying	"You know monkeys are our closest ancestors so it rather surprised me that the face was so elongated."	Cognition, Emotion, Imagination
	"Skulls are fascinating, not so much, ooh, it's a skull, they're such complicated things and sort of important."	Cognition, Emotion
Situating	"I could do this at home."	Cognition, Imagination
Verifying	"Is it a very longish one or is it just sort of short one?"	Cognition, Imagination
	"Benin is Africa, isn't it?"	Cognition
Judging	"Again, there's the problem of size and scale."	Cognition
Solving-Modifying-Suggesting	"I think, could you take those things out? No, that's part of it."	Cognition, Emotion

Table 10. 12 mental operations and examples from this research

7.1.2. Quantitative analysis

Once the comments were categorised, they were counted and analysed in SPSS. Similar to the analysis in the previous chapter related to the time spent in each modality, each of the variables had to be standardised to ensure that all of the values were in proportion with one another. This was due to older participants typically spending a longer amount of time talking about artefacts than the younger group within each modality, as discussed in section 6.1.1, and accordingly, they had more comments. By converting this data into a proportion of their total, all participants' data could be compared uniformly. The resulting standardised values were between 0 and 1. When testing the data for normality, not all of the data were normally distributed. Therefore, all data were analysed using non-parametric tests for consistency.

7.2. Results

Dufresne-Tassé and Lefebvre (1994) presented the results of their framework analysis as a set of four observations. This research similarly analysed participants' comments by: first, comparing all participants' use of each mental operations; second, evaluating grouping categories of mental operations; third, assessing the use of orientations by the participants; and fourth, examining the number of mental operations produced according to the differences in age. The results of each variable's analysis will first be presented in relation to the three modalities. Afterwards, older and younger participants' production of mental operations will be analysed.

7.2.1. Overview of variables in each modality

In the following subsections, the three modalities of artefact presentation, AR on a tablet, 3D models on a laptop, and physical artefacts, will be discussed in relation to the following dependent variables: 1) mental operations; 2) grouping categories; 3) orientation.

7.2.1.1. Mental operations

As the implementation of Dufresne-Tassé and Lefebvre's framework indicated, more than one mental operation could be assigned to each comment. Consequently, participants produced 4,869 mental operations among all three modalities after the comments were coded in NVivo. After the values were standardised, age differences were highlighted for each mental operation within each modality (see Figure 48). As the graph shows, older adults spent most time using the *Taking Note of* and *Explaining-Justifying* mental operations in both the AR on a tablet and 3D models on a laptop modalities and *Explaining-Justifying* and *Comparing-Distinguishing* in the physical modality, while younger adults spent the most time using *Taking Note of* and *Comparing-Distinguishing* in the digital modalities and a more than half of their time in the physical modality using *Comparing-Distinguishing*. This demonstrates that for artefacts seen in the first two modalities, participants spent the most time describing the artefacts or reading the labels. Additionally, older participants frequently provided further explanations to their thoughts about the digital artefacts while younger participants generally compared the digital artefacts to what was familiar to them. Not surprisingly, in the physical modality, participants spent the most time comparing the physical and digital artefacts.

The least used mental operations for both age groups in each of the modalities were *Situating*, *Anticipating*, and *Solving-Modifying-Suggesting*. Out of the 12 mental operations, these three mental operations were each used less than 5% of the time in all three modalities by the older group and less than 3% of the time in all three modalities by the younger participants. Both age groups used the other nine mental operations at least twice as often as they used the *Situating*, *Anticipating*, and *Solving-Modifying-Suggesting* mental operations.

Figure 48. Mental operations within each modality by age

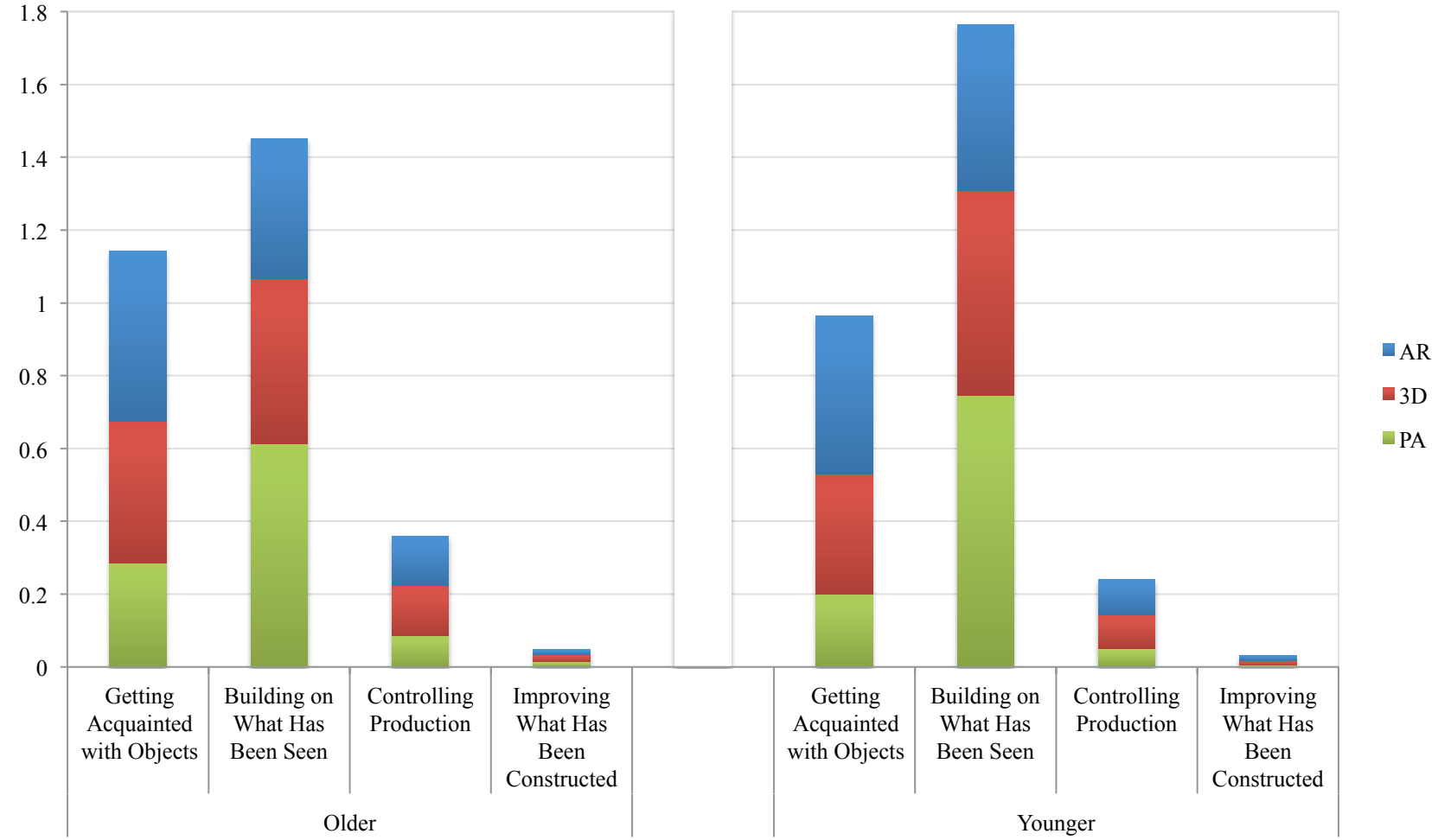


Figure 49. Grouping categories within each modality by age

7.2.1.2. Grouping categories

The 12 mental operations were further classified according to their grouping category (see Table 4 on page 128), and the resulting four categories can be compared in Figure 49. Interestingly, both older and younger people mostly utilised the mental operations in the *Building on What Has Been Seen* category in the physical artefact modality, whereas older adults spent just as much time *Getting Acquainted with Objects* and *Building on What Has Been Seen* in the digital modalities. Younger people spent more time in *Building on What Has Been Seen* in the 3D models on a laptop modality compared to the AR on a tablet modality, but used a comparable number of mental operations in the *Getting Acquainted with Objects* and *Building on What Has Been Seen* categories in the AR on a tablet modality. Both age groups used the *Controlling Production* and *Improving What Has Been Constructed* categories similarly in all three modalities.

7.2.1.3. Orientation

Similar to the mental operations, participants can use more than one orientation for each comment (see Table 5 on page 129). Therefore, the coding in NVivo resulted in a total of 5,724 orientations among all three modalities. These values were standardised and comparisons are presented in Figure 50. As expected, *Cognition* was used the most by both older and younger adults in all modalities. They each spent about the same amount of time using the *Emotion* and *Imagination* orientations, but older adults used both orientations less than half the time as *Cognition*, while younger adults used both orientations about a quarter of the time as *Cognition*.

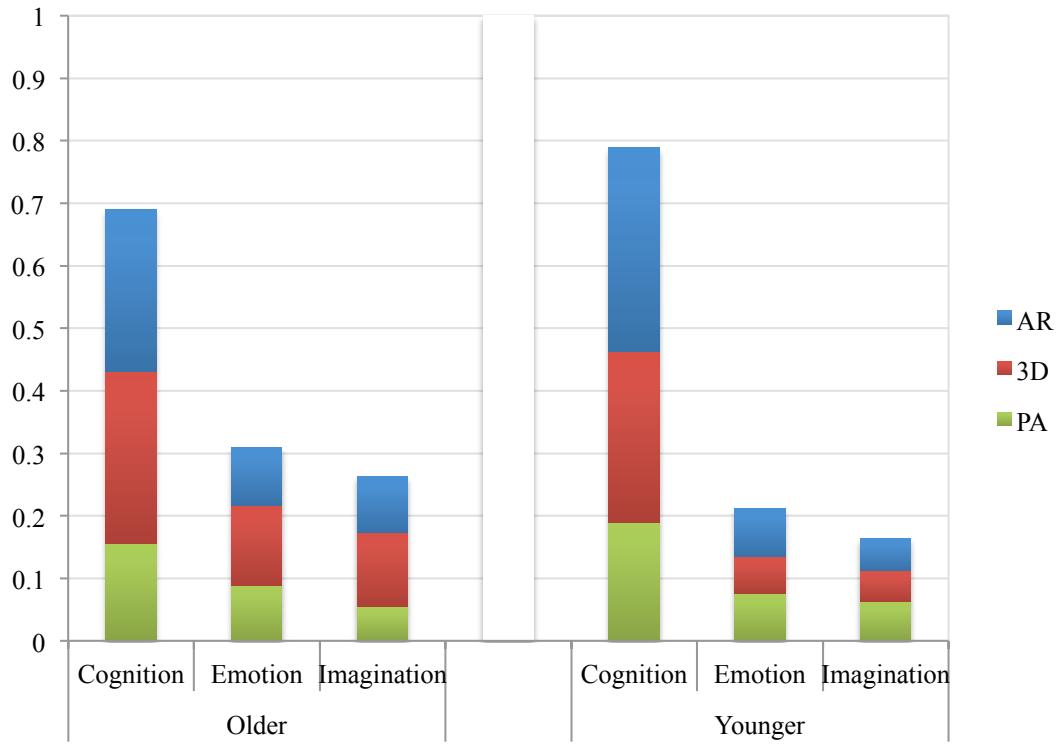


Figure 50. Orientation within each modality by age

7.2.2. Statistical analysis of modality comparisons

To understand the links between the modalities and the production of mental operations or orientations as participants constructed meaning, the following dependent variables will be compared using SPSS: number of mental operations, grouping categories, and orientations.

7.2.2.1. Mental operations in each modality

First, Friedman's ANOVA test was used to explore the links between the modalities and the mental operations used by a participant while interacting with the artefacts. The results in Table 11 show that the change in modality type significantly affected 8 out of the 12 mental operations: *Taking Note of, Identifying, Evoking, Anticipating, Comparing-Distinguishing, Grasping, Explaining-Justifying*, and *Verifying*. For these results, pair-wise comparisons were further analysed using the *post hoc* test

called the Wilcoxon signed-rank test. Since three modalities were used, the critical level of significance is $p = 0.05/3$, which equals 0.0167.

While there was no significant difference between the digital modalities in *Taking Note of* and *Identifying*, the results indicated that the use of the *Taking Note of* mental operation was significantly higher for the AR on a tablet modality when compared to the physical artefacts modality, $T = 96$, $p < 0.005$, $r = -0.67$. It was also significantly higher for the 3D models on a laptop modality when compared to the physical artefacts modality, $T = 101$, $p < 0.005$, $r = -0.66$.

Furthermore, the *Identifying* mental operation was significantly higher for the AR on a tablet modality when compared to the physical artefacts modality, $T = 110$, $p < 0.005$, $r = -0.51$ and for the 3D models on a laptop modality when compared to the physical artefacts modality, $T = 67$, $p < 0.0167$, $r = -0.44$.

Evoking in the 3D models on a laptop modality was significantly higher than in the physical artefacts modality, $T = 50$, $p < 0.005$, $r = -0.50$.

The use of the *Anticipating* mental operation was significantly higher for the AR on a tablet modality when compared to the physical artefacts modality, $T = 0$, $p < 0.0167$, $r = -0.40$ and for the 3D models on a laptop modality when compared to the physical artefacts modality, $T = 0$, $p < 0.0167$, $r = -0.37$.

It was only in the *Comparing-Distinguishing* mental operation where the physical artefacts modality was significantly higher than both of the digital modalities: the AR on a tablet modality, $T = 16$, $p < 0.005$, $r = -0.84$ and the 3D models on a laptop modality, $T = 68$, $p < 0.005$, $r = -0.73$.

Grasping was used significantly more in the AR on a tablet modality than in the physical artefacts modality, $T = 97.00$, $p < 0.0167$, $r = -0.38$.

Mental Operations	Friedman's ANOVA		*Post hoc* Tests Pairwise Comparisons					
			AR / 3D		AR / PA		3D / PA	
	$\chi^2(2)$	*p*	Mdn (IQR)	*p*	Mdn (IQR)	*p*	Mdn (IQR)	*p*
Expressing	1.302	0.527	0.0611(0.1183) / 0.0512 (0.0633)	0.082	0.0611 (0.1183) / 0.0563 0.1072)	0.439	0.0512 (0.0633) / 0.0563 (0.1072)	0.373
Taking Note of	20.150	0.000***	0.3146 (0.2120) / 0.2800 (0.1559)	0.482	0.3146 (0.2120) / 0.1325 (0.1152)	0.000***	0.2800 (0.1559) / 0.1325 (0.1152)	0.000***
Identifying	12.379	0.002***	0.0467 (0.1007) / 0.0278 (0.0683)	0.174	0.0467 (0.1007) / 0.000 (0.0389)	0.001***	0.0278 (0.0683) / 0.000 (0.0389)	0.005**
Evoking	7.252	0.027*	0.000 (0.0430) / 0.0261 (0.0890)	0.080	0.000 (0.0430) / 0.000 (0.000)	0.105	0.0261 (0.0890) / 0.000 (0.000)	0.001***
Anticipating	9.135	0.009*	0.000 (0.000) / 0.000 (0.000)	0.700	0.000 (0.000) / N/A****	0.008**	0.000 (0.000) / N/A****	0.016**
Comparing-Distinguishing	38.956	0.000***	0.1238 (0.2210) / 0.1409 (0.2415)	0.764	0.1238 (0.2210) / 0.3879 (0.2882)	0.000***	0.1409 (0.2415) / 0.3879 (0.2882)	0.000***
Grasping	11.082	0.003***	0.0377 (0.0702) / 0.0056 (0.0360)	0.023	0.0377 (0.0702) / 0.000 (0.0494)	0.014**	0.0056 (0.0360) / 0.000 (0.0494)	0.886
Explaining-Justifying	6.731	0.034*	0.1628 (0.1374) / 0.2240 (0.1730)	0.001***	0.1628 (0.1374) / 0.2034 (0.1622)	0.007**	0.2240 (0.1730) / 0.2034 (0.1622)	0.655

AR = AR on a tablet modality; 3D = 3D models on a laptop modality; PA = physical artefacts modality; Mdn = median; IQR = Interquartile range; $\chi^2(2)$ = test statistic for Friedman's ANOVA test; *p* = p-value; *r* = effect size; * = $p < 0.05$; ** = $p < 0.0167$ (for *post hoc* tests only); *** = $p < 0.005$; **** = data is constant and therefore omitted

Table 11. (continued on next page). Summary of Friedman's ANOVA and *post hoc* tests on modalities and mental operations

Friedman's ANOVA			Post-hoc Tests Pairwise Comparisons					
Mental Operations	$\chi^2(2)$	***p***	**AR / 3D**		**AR / PA**		**3D / PA**	
			Mdn (IQR)	***p***	**Mdn (IQR)**	***p***	**Mdn (IQR)**	***p***
Situating	3.000	0.226	0.000 (0.000) / 0.000 (0.0184)	0.031	0.000 (0.000) / 0.000 (0.000)	0.571	0.000 (0.0184) / 0.000 (0.000)	0.151
Verifying	14.145	0.001***	0.0360 (0.0641) / 0.0423(0.0738)	0.836	0.0360 0.0641) / 0.000 (0.0484)	0.005**	0.0423 (0.0738) / 0.000 (0.0484)	0.003***
Judging	0.715	0.715	0.0272 (0.0848) / 0.0352 (0.0953)	0.919	0.0272 (0.0848) / 0.0231(0.0500)	0.193	0.0352 (0.0953) / 0.0231 (0.0500)	0.120
Solving-Modifying-Suggesting	3.976	0.145	0.000 (0.1726) / 0.000 (0.0308)	0.082	0.000 (0.1726) / 0.000 (0.000)	0.439	0.000 (0.0308) / 0.000 (0.000)	0.373

AR = AR on a tablet modality; 3D = 3D models on a laptop modality; PA = physical artefacts modality; Mdn = median; IQR = Interquartile range; $\chi^2(2)$ = test statistic for Friedman's ANOVA test; p = p-value; r = effect size; * = $p < 0.05$; ** = $p < 0.0167$ (for *post hoc* tests only); *** = $p < 0.005$

Table 11. (continued from previous page). Summary of Friedman's ANOVA and *post hoc* tests on modalities and mental operations

Participants used *Explaining-Justifying* significantly more in the 3D models on a laptop modality than in the AR on a tablet modality, $T = 167.00$, $p < 0.005$, $r = -0.49$. This mental operation was also significantly higher for the physical artefacts modality when compared to the AR on a tablet modality, $T = 211.50$, $p < 0.0167$, $r = -0.42$.

In using the *Verifying* mental operation, both the AR on a tablet modality, $T = 126$, $p < 0.0167$, $r = -0.44$ and the 3D models on a laptop modality, $T = 120.50$, $p < 0.005$, $r = -0.45$ were significantly higher than the physical artefacts.

7.2.2.2. Grouping categories in each modality

Next, the Friedman's ANOVA test results for the mental operations were analysed according to their grouping categories. As Table 11 shows, the analysis for the mental operations determined that there was no significant difference among the three modalities in the *Solving-Modifying-Suggesting* mental operation. This is the only mental operation in the *Improving What Has Been Constructed* category. Therefore, the change of modality type did not significantly affect this grouping category.

The *Controlling Production* category contains the mental operations *Situating, Verifying*, and *Judging*. As *Verifying* was the only mental operation among those three that had a significant difference, the change in modality type in the *Controlling Production* category was significantly affected only by the *Verifying* mental operation.

The last two categories, *Getting Acquainted with Objects* and *Building on What Has Been Seen* are a bit more complicated since almost all the mental operations within each category have significant differences.

The *Getting Acquainted with Objects* category includes the mental operations *Expressing, Taking Note of*, and *Identifying*. From the analysis of the mental operations, *Expressing* was not significantly affected by the change of modality.

However, the change in modality type significantly affected *Taking Note of* and *Identifying*. While there was no significant difference between the digital modalities in both those mental operations, the digital modalities for each of them were significantly higher than the physical artefacts modality. As a result, participants spent the most time *Getting Acquainted with Objects* in the digital modalities by *Taking Note of* and *Identifying*.

The *Building on What Has Been Seen* category comprises *Evoking, Anticipating, Comparing-Distinguishing, Grasping*, and *Explaining-Justifying*. *Building on What Has Been Seen* in the 3D models on a laptop modality seemed to involve significantly more *Evoking* and *Anticipating* than in the physical artefacts modality, as well as significantly more *Explaining-Justifying* than in the AR on a tablet modality.

Building on What Has Been Seen in the AR on a tablet modality encompassed a significantly higher use of *Anticipating* and *Grasping* than in the physical artefacts modality.

In the physical artefacts modality, *Building on What Has Been Seen* included significantly more *Explaining-Justifying* and *Comparing-Distinguishing* when compared to the AR on a tablet, as well as more *Comparing-Distinguishing* compared to the 3D models on a laptop modality.

7.2.2.3. Orientation in each modality

The Friedman's ANOVA test was also used to determine if any of the artefact modalities influenced the *Cognition, Emotion*, and *Imagination* orientations of a participant while interacting with the artefacts. The results, shown in Table 12, indicate that the change in modality type only significantly affected the use of *Cognition*. The Wilcoxon signed-rank test was run as a *post hoc* test using a significance of 0.0167. Based on this, the results showed that the use of *Cognition* was significantly higher for the AR on a tablet modality when compared to the physical artefacts modality, $T = 106$, $p < 0.005$, $r = -0.61$. In addition, the use of

Cognition was significantly higher for the 3D models on a laptop modality than the physical artefacts modality, $T = 66$, $p < 0.005$, $r = -0.71$.

7.2.2.4. Age differences and mental operations

Last, the Mann-Whitney test was run to compare the production of mental operations and age in each modality (see Table 13). Surprisingly, there was a significant difference between older and younger adults and the number of mental operations used only in the 3D models on a laptop modality. To further investigate these differences, *post hoc* tests comparing age groups were run on the mental operations in the 3D models on a laptop modality using the Mann-Whitney test. The results in Table 14 show that the older group tended to produce significantly more mental operations than the younger group in this modality in four mental operations: *Expressing, Explaining-Justifying, Verifying*, and *Solving-Modifying-Suggesting*. Interestingly, each of these mental operations belongs to a different grouping category. Since *Solving-Modifying-Suggesting* is the only mental operation in the *Improving What Has Been Constructed* category, older participants spent significantly more time using this category when interacting with artefacts. It was only in *Comparing-Distinguishing* that the younger people appeared to be significantly more productive. Tests on age differences and orientation were conducted; however, explanations according to the mental operations best clarified the use of orientations and the inclusion of additional test results on orientation would be redundant.

Orientation	Friedman's ANOVA		Post-hoc Tests Pairwise Comparisons					
			AR /3D		AR /PA		3D /PA	
	$\chi^2(2)$	*p*	Mdn (IQR)	*p*	Mdn (IQR)	*p*	Mdn (IQR)	*p*
Cognition	19.551	0.000***	0.3030 / 0.2658 (0.2583-0.1496)	0.474	0.3030 / 0.1756 (0.2583-0.0816)	0.000**	0.2658 / 0.1756 (0.1496-0.0816)	0.000***
Emotion	0.167	0.920	0.0893 / 0.0782 (0.0761-0.0823)	0.767	0.0893 / 0.0718 (0.0761-0.0613)	0.533	0.0782 / 0.0718 (0.0823-0.0613)	0.618
Imagination	1.084	0.582	0.0662 / 0.0682 (0.1010-0.1329)	0.385	0.0662 / 0.0538 (0.1010-0.0374)	0.397	0.0682 / 0.0538 (0.1329-0.0374)	0.091

AR = AR on a tablet modality; 3D = 3D models on a laptop modality; PA = physical artefacts modality; Mdn = media
IQR = Interquartile range; $\chi^2(2)$ = test statistic for Friedman's ANOVA test; *p* = p-value; *r* = effect size; * = $p < 0.05$; ** = $p < 0.0167$ (for *post hoc* tests only); *** = $p < 0.005$

Table 12. Summary of Friedman's ANOVA and *post hoc* tests on modalities and orientation

Modality	Older (65+) Mdn (IQR)	Younger (18-21) Mdn (IQR)	*U*	*p*	*r*
AR	0.0250 (0.0290)	0.0176 (0.0243)	154.00	0.218	-0.20
3D	0.0301 (0.0236)	0.0166 (0.0089)	73.50	0.000*	-0.54
PA	0.0237 (0.0180)	0.0193 (0.0145)	130.00	0.058	-0.30

AR = AR on a tablet modality; 3D = 3D models on a laptop modality; PA = physical artefacts modality; Mdn = median; IQR = Interquartile range; *U* = test statistic for Mann–Whitney test; *p* = p-value; *r* = effect size; * = $p < 0.005$

Table 13. Summary of Mann-Whitney test on production of mental operations and age in each modality

Mental Operation	Older (65+) Mdn (IQR)	Younger (18-21) Mdn (IQR)	*U*	*p*	*r*
Expressing	0.0759 (0.0712)	0.0270 (0.0482)	73.50	0.000**	-0.54
Taking Note of	0.2820 (0.1092)	0.2336 (0.2095)	197.00	0.941	-0.43
Identifying	0.0331 (0.0672)	0.0109 (0.0838)	172.50	0.441	-0.12
Evoking	0.0307 (0.0883)	0.0139 (0.0890)	186.50	0.710	-0.06
Anticipating	0.000 (0.0115)	0.000 (0.000)	151.00	0.068	-0.32
Comparing-Distinguishing	0.0728 (0.1503)	0.1667 (0.4122)	99.00	0.005*	-0.43
Grasping	0.0223 (0.0517)	0.000 (0.0274)	142.00	0.095	-0.27
Explaining-Justifying	0.2646 (0.1260)	0.1807 (0.1946)	127.50	0.050*	-0.31
Situating	0.000 (0.0293)	0.000 (0.000)	157.00	0.149	-0.23
Verifying	0.0534 (0.0651)	0.000 (0.0619)	108.50	0.011*	-0.40
Judging	0.0162 (0.1163)	0.0501 (0.0841)	183.50	0.659	-0.07
Solving-Modifying-Suggesting	0.0155 (0.0335)	0.000 (0.0121)	133.50	0.049*	-0.31

Mdn = median; IQR = Interquartile range; *U* = test statistic for Mann–Whitney test; *p* = p-value; *r* = effect size; * = $p < 0.05$; ** = $p < 0.005$

Table 14. Summary of Mann-Whitney test on mental operations and age in the 3D models on a laptop modality

7.2.3. Summary of findings

- Of the 12 mental operations, the only significant difference between the two digital modalities was the *Explaining-Justifying* mental operation, which is part of the *Building on What Has Been Seen* grouping category. Based on this, participants were not passive and constructed meaning while interacting with digital artefacts in both modalities using comparable mental operations.
- There were no significant differences between the two digital modalities and the orientations used. Therefore, participants spent a similar amount of time utilising *Cognition*, *Emotion*, and *Imagination* in each digital modality.
- The only significant difference between older and younger participants when using the mental operations was in the 3D models on a laptop modality
- There were significant differences between the digital modalities and the physical modality in 8 out of 12 mental operations as well as the *Cognition* orientation, yet interacting with artefacts in the digital modalities first did not lead to a significantly lower use of *Emotion* in the physical artefacts experience. As a result, participants were not passive due to their use of mental operations and orientations, and they still found meaning when viewing the physical artefacts.

7.3. Conclusion

The purpose of this analysis was to understand how participants gave meaning to artefacts while interacting with them on devices outside of a museum. Focus was placed on the verbalisation of their experience, first in two digital modalities, 3D models on a laptop and AR on a tablet, and then lastly in the physical modality. Comments were coded according to Dufresne-Tassé and Lefebvre's framework. In addition to differences in modality, comparisons between older and younger adults were explored to determine whether age was a factor in their experience.

The next chapter discusses this analysis along with the previous chapter's analysis to explain the results and their significance in relation to previous research discussed in the literature review.

Chapter 8: Discussion

The previous two chapters demonstrated through quantitative and qualitative analysis that older and younger adults are able to make emotional connections with digital artefacts and meaning while interacting with them using personal devices outside a museum. Moreover, they were still able to emotionally connect with physical artefacts and meaningfully engage with them even though they first interacted with the digital artefacts.

This chapter addresses the aims presented at the beginning of Chapters 6 and 7 and expands on the importance of understanding whether emotion and meaning emerge from interactions with digital cultural heritage artefacts.

8.1. Summary of the user-digital artefact interaction outside a museum

The older and younger participants in this study were able to make emotional connections and construct meaning from their interactions with digital artefacts through two digital modalities because of several reasons, which are summarised in Figure 51. The users each brought their own personal backgrounds, along with their memories and imaginations, to the experience of interacting with digital artefacts. This was manifested in their usage of the mental operations. The digital modalities' capabilities allowed users to personalise their experiences and control their interactions with artefacts, which supported their individuality. Yet the digital modalities did not distract participants from making of personal connections with the digital artefacts because interactions between participants and artefacts led to emotion and meaning through their use of mental operations and orientations. Even though the artefacts were seen through a computer screen, participants still recognised an object's distinct colour, shape, pattern, and texture. Based on these elements, participants recalled memories, imagined artefacts being used, and used their knowledge to make sense of artefacts. Insight was gained about their interactions through their use of mental operations and orientations. The resulting interaction among the users, digital modalities, and artefacts enabled users to have an engaging experience that led to emotions and meaning.

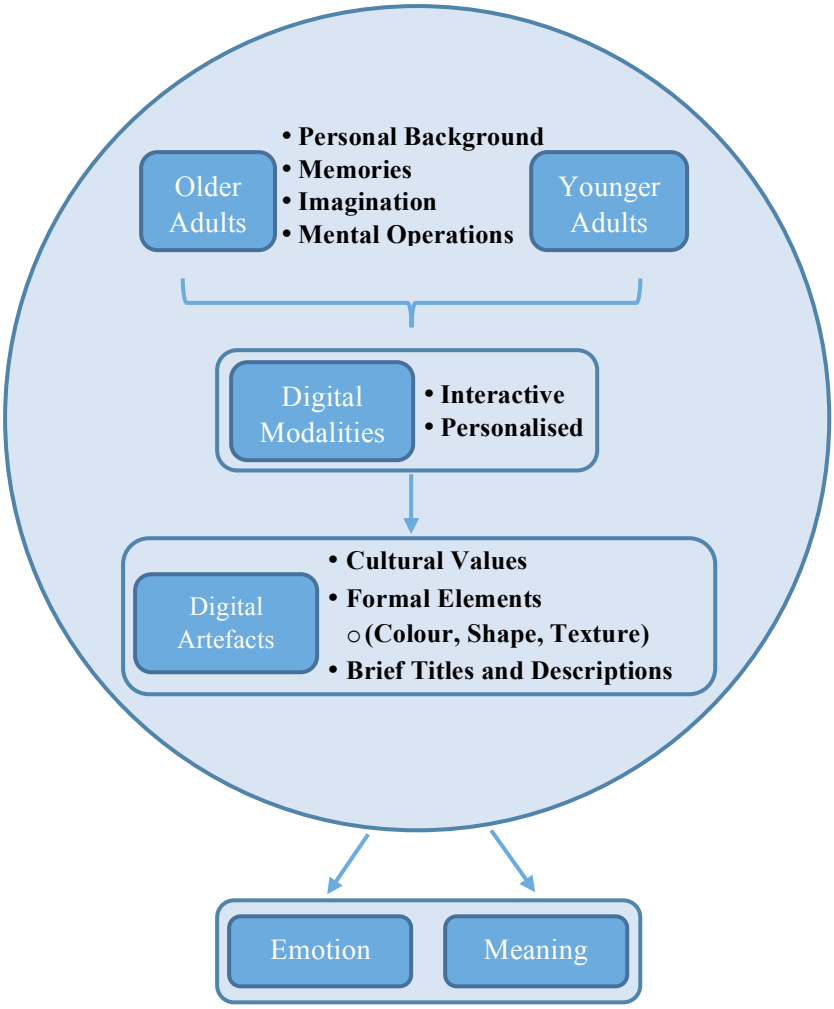


Figure 51. Diagram summarising the user-digital artefact interaction outside a museum, resulting in emotion and meaning

8.2. Emotional responses to digital artefacts

8.2.1. Older and younger adults

Past studies have reported differences between older and younger people and their technology backgrounds and skills (Wu et al. 2015; Olson et al. 2011; Broady, Chan, and Caputi 2010) and the participants in the main study had a significantly different number of museum visits (see section 6.2.1); therefore it was surprising that for many of the emotion variables, the results showed no significant differences between these two age groups across the digital modalities. A possible explanation is that

older people are more likely to use technology if it supports their well-being (Olson et al. 2011). Since they tend to visit museums more often than other age groups (NEA 2015; McIntyre 2007), they welcomed the opportunity to interact with museum artefacts that were digitised and had an enjoyable experience. Although the younger participants had a significantly higher familiarity with AR than the older group, participants felt a consistent number of emotions in each digital modality, which indicates that both modalities were able to facilitate emotional connections. Participants felt emotions of varying valence and arousals, with most arousal scores being high. These were consistent in each modality, suggesting that one modality did not influence emotions that were more or less pleasant or intense. However, it has been argued that 3D computing experience does not influence enjoyment in virtual museums (Sylaiou et al. 2010), which include digital objects.

Furthermore, these two groups have similar motivations for visiting physical museums. Older people aged 65 and over are seeking new experiences, entertainment, and learning opportunities (Kelly et al. 2002). They also welcome opportunities to reminiscence (Aldridge and Dutton 2009). Younger adults want engaging experiences, innovative services, individualised learning, and emotional connections (Shaw and Krug 2013; Gofman, Moskowitz, and Mets 2011; Kelly and Groundwater-Smith 2009). Interacting with the 3D models on a laptop and AR on a tablet modalities was both a new experience due to the participants' relatively low familiarity with these types of technologies, and an engaging experience due to their high rankings of enjoyment. These modalities allowed participants to control the interaction, which let them discover the artefacts at their own pace. This contributed to a more personalised artefact viewing experience. There were also opportunities to learn during the time spent interacting with the artefacts; this effective engagement with digital artefacts agrees with the study by Hogsden and Poulter (2012b). The emotion variables indicate that both age groups made a similar number of emotional connections in each digital modality, and neither modality resulted in emotions in either extreme, exemplified by their comparable S_1 and S_2 scores.

8.2.2. Digital modalities outside a museum

The results in Chapter 6 showed that older and younger adults enjoyed interacting with digitised artefacts outside of a museum in both modalities, AR on a tablet and 3D models on a laptop. Despite the relative unfamiliarity with these modalities and the absence of supplementary context that a physical museum might provide, such as displaying artefacts in a certain timeline or near similar artefacts, using specific lighting, or giving important objects a place of prominence on a wall or in a display case, the modalities enabled participants to experience emotions while viewing and interacting with 3D artefacts. This contrasts with similar research that indicated participants' responses were influenced by the museum environment in which the original oil painting was displayed (Locher, Smith, and Smith 2001; Taylor 2001). However, the results of this study support the findings of Gadsby (2011), which concluded that museums should reconsider the exhibit methods used to influence visitors' emotional responses and allow visitors to 'reflect and form their own values'. Although Gadsby was referring to exhibits inside a museum, some virtual museums similarly display digital artefacts within some form of context (Kotsopoulos et al. 2010), and the results of this study indicate that this is not essential for viewers to have an emotional connection.

Past studies investigated university students' emotional and cognitive experiences when interacting with digital cultural heritage artefacts online and also used the think-aloud method (Zahidi, Lim, and Woods 2014; Zahidi, Yan Peng, and Woods 2013). However, their digital content consisted of photos, videos, links, and narratives, rather than 3D cultural heritage models. The researchers were concerned with how users, who were not experts in cultural heritage, emotionally engaged with the website's usability, including layout, social media integration, and navigation. Instead, this study builds upon their research by focusing on user's emotional responses to the digital artefacts themselves, not the modalities.

In this PhD study, the artefacts were digitised, not located within a museum, and offered brief descriptions, yet participants experienced emotions while interacting with the artefacts, as evidenced by their responses on the questionnaires and their

verbalised comments. The results in Chapter 6 argued that the change in modality type did not significantly affect any of the emotion variables, which included the emotion count, their S_1 (valence and dominance), and their S_2 (arousal) scores. This agrees with Cameron (2007) in the sense that many of the properties of a physical artefact were apparent in the digital artefacts, including colour, shape, and texture, thereby generating similar emotional responses. Accordingly, both digital modalities enabled a similar number of emotional responses that did not fall into either extreme on the valence and arousal scales. While the emotional responses were indicated by participants on questionnaires, emotions were also revealed through their comments, verifying that participants made an effort to understand museum objects (Taylor 2009). These comments were analysed according to Dufresne-Tassé and Lefebvre's framework, which included the *Emotion*, *Cognition*, and *Imagination* orientations. Barrett et al. (2007) stated that consciously experiencing emotion involves 'past feelings (memories), hypothetical feelings (imaginings), or feelings that are occurring in the moment (on-line experiences)'. These emotional experiences are evident in the comments made by the older and younger participants as they interacted with the digital artefacts; the comments also indicate how participants constructed meaning during their interactions. For example, both older and younger participants referenced memories:

> Older participant #3 interacting with the comb in the AR on a tablet modality: *"Now I'll tell you what that reminds me of, I have a collection of Japanese page turners. Japanese cut them in vaguely the same shape but it doesn't have [draws pattern in the air with finger], and then they decorate them on one side with all sorts of different kinds of things and that reminds me of that."*

> Younger participant #14 interacting with the baboon skull in the 3D models on a laptop modality: *"It reminds me of my grandparents' home because my great-aunt was married to a man from Africa so in exchange for some money they gave my family a lot of African artefacts. The apartment was full of artefacts."*

With regards to hypothetical feelings (imaginings), older and younger participants alluded to the creator of an artefact or imagined themselves wearing an artefact:

> Older participant #12 interacting with the gourd in the AR on a tablet modality: *"It's very interesting, I love the patterns. I wonder why it's that colour, whether it's been stained presumably, has it or painted, I guess. I don't know what colour the seed pot was originally. That's very beautiful."*

> Younger participant #4 interacting with the necklace in the 3D models on a laptop modality: *"This one is colourful I think, it's really nice. I can tell, now from seeing it on a screen and zooming in, I can see the neck is actually really big […] and I can feel like when you wear it, it's kind of quite heavy and you must have a very big neck to go around it. It's actually really strong, I can tell the very fine detail of the back of the necklace where you can see the hook that joins the two together."*

Participants also had the following 'in the moment' reactions:

> Older participant #2 interacting with the Kora sword in the 3D models on a laptop modality: *"Thought comes of all the cruelties all over the world and so people would be always using it to kill each other which is so sad it reminds me of the Syrian thing now, this big crisis and it's a big issue really, it's quite a, it's an object I would like not to see at all being used."*

> Younger participant #1 interacting with the bronze bust in the AR on a tablet modality: *"The face looks happy so I guess it makes me feel happy."*

These examples indicate that participants were able look past any limitations of the digital artefacts and only focused on the object itself (Locher, Smith, and Smith 2001). The participants in this study were able to not only make emotional connections with the digital artefacts, but their comments explained the meaning behind their emotions.

8.3. Meaning and interaction with digital artefacts

8.3.1. Older and younger adults

When comparing two diverse age groups such as older and younger adults, there continues to be a disparity between them in their awareness and use of new technologies (Wu et al. 2015; Prensky 2001). In spite of this, the results of this study show that older participants experienced similar numbers of mental operations and orientations as the younger group in the AR on a tablet modality, and the 3D models on a laptop modality encouraged them to contribute more thoughts and responses. In this modality, older people used significantly more mental operations than younger people in 4 out of 12 mental operations: *Expressing*, *Explaining-Justifying*, *Verifying*, and *Solving-Modifying-Suggesting*. Since *Expressing* is the sole mental operation that can be connected with only *Emotion* and *Imagination*, not *Cognition* (Fairchild 1991), its higher use also increased older participants' use of the *Emotion* orientation. This resulted in the older group also having a higher *Emotion* orientation than younger people in the 3D models on a laptop modality, which makes sense as they were more familiar with 3D models compared to AR technology (see section 6.2.1); thus, they were more likely to emotionally connect with artefacts in the more familiar modality.

These age differences disagree with Dufresne-Tassé and Lefebvre's (1994) findings that age did not affect the production of mental operations and orientations. However, their study involved participants aged 25-65, whereas this analysis compared young adults aged 18-21 and older adults who were 65 and over, two age groups that are still divided in their knowledge of new technologies (Wu et al. 2015). They also have contrasting museum experiences and different life experiences, as older people generally have more past experiences that they can refer to when trying to understand artefacts. Dufresne-Tassé and Lefebvre's study also focused on physical artefacts in a museum instead of digitised artefacts viewed on personal devices, of which opposing age groups have different skills. In actuality, when users access 3D models of museum artefacts online, they will be doing so using their own

personal devices and thus, older and younger adults should already be familiar with the technology, or at least be willing to learn.

When visiting museums, older people expect historical reminiscence (Sheng and Chen 2012), which leads to experiencing emotions (Wood and Conway 2006); this, along with their past experiences, is reflected in their higher output of mental operations, more detailed comments, and *Emotion* orientation compared to younger adults. Therefore, the results of this study suggest that interacting with digital artefacts on personal devices is effective for making emotional connections and meaning regardless of the user's technology skills. This knowledge can assist with concerns related to museum accessibility for the elderly, homebound, or disabled (Thongnopnua 2013; Kelly et al. 2002) since viewing digital artefacts online from their homes can offer a more comfortable, leisurely experience for these groups, without sacrificing the emotional and meaningful experiences one expects in a museum. Moreover, since the Internet and tablets are being considered by older people as tools for health information and autonomy (Castro et al. 2011; Harrod 2011), they are increasingly becoming more technology-savvy. When older people are comfortable using technology, they will have more options for accessing museum collections. As mentioned, younger people also constructed meaning, verifying that the digital modalities are a viable option for creating engaging experiences and revitalising the younger group's perception of museums as being 'boring' with objects that can only be looked at (Kelly and Groundwater-Smith 2009).

Understanding that older and younger participants interact with digital artefacts using similar mental operations and orientations as visitors to physical museums has important implications. Digital artefacts can benefit current and potential museum visitors seeking to access collections away from a museum (see section 2.3.3), and these advantages are strengthened when interactions with artefacts lead to emotion and meaning. Studies have shown that digitised artefacts are important for museum and research purposes such as preserving a copy of an artefact, sharing copies with researchers around the world, viewing a complete artefact that is damaged in real life, and observing changes to the physical artefact over time (Hess et al. 2011; Saggio and Borra 2011; Arnold 2008; Liarokapis and White 2005). However, understanding

how non-researchers and non-museum personnel contribute to the importance of digital artefacts is also essential, as these groups represent a considerable sector of potential and current museum visitors and supporters. The results of the main study show that older and younger participants' interactions with digital artefacts led to emotions and meaning. This is significant as experiencing emotions and meaning can result in a broader museum visitor audience for museums. As a result of this engagement, users could become repeat visitors to both the online and physical museum, tell their family and friends about their positive experiences, and share their experiences online through social media, blogs, and even reviews. This helps to build a relationship with a museum and its collections. Users currently have the ability to access digital artefacts online, but if an emotional connection or meaning is not formed, further visits to a museum, either digital or physical, may not occur.

8.3.2. Digital modalities outside a museum

As participants' comments demonstrate, emotion and meaning were usually linked. These connections were based on the interaction between the participant (viewer or user) and the object (3D model of a cultural heritage artefact). Not all participants experienced emotions when interacting with an artefact, and viewing the same artefact did not always lead to similar emotional responses from participants. This is in line with researchers such as Pearce (1994b) and Weil (1997), who maintained that the meaning of objects depends on the viewer's interaction with the object. Participants in this study constructed meaning through the use of Dufresne-Tassé and Lefebvre's framework of mental operations and orientations in both digital modalities. Out of 12 mental operations, the only significant difference between the two digital modalities was in the use of the *Explaining-Justifying* mental operation. Despite the results highlighting the 3D models on a laptop modality as having a significantly higher use of *Explaining-Justifying* than the AR on a tablet modality, the *Explaining-Justifying* mental operation is only one of five mental operations that form the *Building on What Has Been Seen* grouping category. This implies that both digital modalities were comparable in how meaning emerged through interactions with artefacts; they did not merely examine the artefacts (Dufresne-Tassé and Lefebvre 1994). Besides the difference in one mental operation, there was no

significant difference between the two digital modalities and any of the three orientations. This further provides evidence that both the website and AR app were similarly effective in enabling meaningful experiences through *Cognition*, *Emotion*, and *Imagination*.

This comparable usage of Dufresne-Tassé and Lefebvre's framework in both digital modalities is important as it establishes that participants were able to focus on the artefacts and not the modalities themselves, even though they were generally unfamiliar with AR and only moderately familiar with 3D models. The results challenge the beliefs that the computer screen is a barrier that can lead to detachment and prevents viewers from creating personal connections or meaning (Kalay 2008; Orr 2004). If the older and younger groups were unable to construct meaning while interacting with digital artefacts through recognition or remembering, they would have lost interest and stopped trying to connect with the artefacts in both the digital modalities (Hooper-Greenhill 1999b; Pearce 1994b). Museum personnel should be assured that viewers who access digital artefacts through personal devices are able to make emotional connections and meaning.

Hogsden and Poulter (2012b) recognised that viewing a digital museum artefact on a website away from a physical museum context promoted 'meaningful dialogue', which agrees with the results of this study. They were particularly interested in responses to an artefact that originated in the country where the viewer is located and included videos from the curator's point of view, as well as publications related to the artefact of a bark shield. Despite differing study aims, the results of this study build upon Hogsden and Poulter's findings. The older and younger participants interacted with digital artefacts that were not necessarily part of their own culture, yet their interactions resulted in meaning through the use of the mental operations and orientations, and both the digital modalities enabled them to do so. Since the modalities did not include other forms of context like videos, the meanings given to artefacts were based solely on the interaction between the viewer and digital artefact.

8.4. Digital cultural heritage artefacts

Other researchers supported the use of supplementary context with cultural artefacts. In contrast with Pearce (1994b) and Weil (1997), who argued that artefacts' meanings are based on the viewer-object interaction and therefore cannot be misinterpreted, Beaudoin (2012) emphasised that when digitising cultural artefacts, context should be preserved to eliminate the prospect of misinterpreting the artefact. Likewise, Svensson (2008) stated that 'objects can not speak for culture'; text is needed to put the artefact into context. This is also supported by Vermeylen and Pilcher (2009), who argued that digitised indigenous heritage objects within a virtual room are not beneficial for indigenous people since viewers may not fully understand an object's significance. They suggested using collaborative methods to integrate other forms of engagement on the website, for example video or audio, so viewers can understand the object from different viewpoints. Rahaman and Tan (2011) agreed with encouraging multiple perspectives of interpreting cultural heritage, but instead of assistance from heritage professionals, they concentrated on end-users, as meaning making is a 'dynamic process'. The results of this study follow Rahaman and Tan's efforts to bring attention to the end-user's interpretation instead of the museum professional's; however, they intended to increase communication channels between end-users. This study similarly focused on end-users' interpretations by understanding their utilisation of mental operations and orientations, which also highlighted meaning as an individualised process. As such, this study showed that interaction with a 3D artefact, along with only a neutral description to provide background information, enabled each participant to understand and appreciate the artefacts.

There was no influence from the museum side or cultural side through supplementary resources, and participants had the freedom to draw conclusions based on their own personal backgrounds and knowledge. Here, the interaction offered by the personal devices provided the supplementary information suggested by both Vermeylen and Pilcher (2009) and Hogsden and Poulter (2012a). In place of video or audio, the interaction facilitated movement of the artefacts, and participants

had the option to see the artefacts as stationary and innocuous in addition to functional because their movement of the artefacts could simulate how they were used. Both perspectives contributed to their emotional responses to artefacts, as well as their understanding and meaning of them. That is not to say that complementary text, video, audio, or other digital methods should not be utilised along with the digital artefacts. For participants whose interaction with artefacts was brief and therefore less meaningful, implied by their lower production of mental operations and orientations, this added context would be helpful for understanding the artefact's meaning or intention. Nonetheless, participants who had cultural connections to artefacts and those who did not both constructed meaning from interactions with digital artefacts viewed without this extra information.

Moreover, Dudley (2010) referred to museum objects as 'object-subject interaction', which is triggered by the physical characteristics of an object. This interaction also relies on the viewer's sensory (including emotional) responses and meanings given to objects. Natural artefacts aside, many ethnographic and cultural artefacts' attributes are reflected through their craftsmanship, and therefore, cultural values are transferred over to the digital artefact (Brown 2007). This in turn generates a consistent response from the viewer, whether the artefact is first seen in its original or digital form. The participants in this study were able to respond emotionally and make meaning based on the digital artefact's physical characteristics, which they could evaluate by controlling how they interacted with them using the personal devices. By zooming in and rotating the digital artefacts, participants confirmed whether the artefact was made of wood or bronze, whether it was hollow, and whether patterns continued onto the other side of an artefact or were completely different. Conversely, Cameron (2007) stated that the 'status of copies from non-digital originals still remains ambiguous' due to the lack of transparency about its production. Insight on this issue is provided by this study, as the digital artefacts were clearly defined to be 3D models and the participants' interactions with them were through personal devices. The digital modalities were presented as an opportunity to interact with 3D models of museum artefacts, not recreations of artefacts intended to be separate artefacts in their own right.

As the artefacts they were viewing were 3D models of physical artefacts, participants also commented on their quality and realism. This occurred in the participants' production of the *Judging* mental operation. Some older and younger participants judged the same artefacts differently in the two digital modalities, even though others did not share the same opinions. This indicates that there is value for integrating digital artefacts in both a website and an AR app, as people have varying perspectives and backgrounds. Furthermore, there was no significant difference in the change in modality and the production of comments related to *Judging*, nor was there a significant difference between the two age groups and their use of *Judging*. In total, *Judging* comments represented less than 7% of the mental operations used in each modality, which is in line with the percentage reported in Dufresne-Tassé and Lefebvre's (1994) study that took place in physical museums. Overall, participants were able to accept the digital artefacts as representations of the original, and interactions with digital artefacts led to emotions and meaning.

8.5. Subsequent viewing of physical artefacts

8.5.1. Older and younger adults still respond emotionally to physical artefacts

Participants found both digital modalities engaging and were able to emotionally connect with them, yet this did not lessen their enjoyment and emotional responses to the physical artefacts. Although the older and younger groups ranked the digital modalities similarly, the older participants' enjoyment significantly increased in the physical artefacts modality, despite the physical artefacts being viewed outside a museum. This could be supported by their significantly higher museum visits than the younger participants (see section 6.2.1) and past research that found that museums have a higher percentage of older visitors compared to young adult visitors (NEA 2015; McIntyre 2007).

Due to the different conditions for the originals and copies, the results of this study conflict with the results of Locher, Smith, and Smith (2001), which showed that the reproductions generated different responses to the physical oil paintings. Even though they focused on paintings, which are different from artefacts, both enable

emotional responses and are part of museums' collections. Copies of paintings and artefacts retain many of the original's formal elements, which are what the viewer sees when trying to understand artefacts. While Locher, Smith, and Smith did not specifically investigate emotional responses, they did rate how surprising, interesting, and pleasant the artworks were, and these ratings significantly differed between the copies and original paintings. The similar valence and arousal scores for each modality in Chapter 6's results show that participants did not have significantly different emotional responses to the digital and physical artefacts. While emotional responses to these artefacts may be different if they were viewed in a museum, Locher, Smith, and Smith (2001) indicated that some of the emotional responses were due to different aspects of the physical museum. However, even outside of a museum, the older group enjoyed the physical artefacts the most, but the emotional responses for both age groups were consistent for all modalities.

After conducting research comparing responses to physical and digital copies of artworks, Taylor (2001) claimed that the original artworks were easiest for identifying emotional content and intensity of emotions. He specifically focused on the emotions expressed in a painting (identification) rather than the emotions felt when looking at a painting (interpretation). Although this approach differs from this study, the results are comparable. Similar to this research, he found no significant difference in the number of emotions identified in the originals and any of the copies. In addition, Taylor's participants reported intensities of emotions that were significantly higher for the originals and the coloured slide copies when compared to the other conditions. The slide condition in Taylor's study is comparable to both the 3D models on a laptop and the AR on a tablet modalities since they showed textures and colours, which contributed to the intensity of emotional responses by the participants.

Later, Taylor (2009) discussed the pre-test conducted during this earlier study (2001) where the painting was moved from the gallery to the basement storage. He found that the average number of emotions identified by the participants decreased, which contrasts with the results of this PhD study where the number of emotions remained similar in all three modalities. However, the emotional responses for the original

painting were influenced by the physical context of the museum, including the colour of the museum's walls, its floors, and other visitors (Taylor 2001). Even though participants viewed all modalities outside of the museum, this information is beneficial because it indicates that participants were capable of emotionally connecting with digital artefacts in two different modalities, and their emotional responses did not significantly increase nor decrease when seeing the physical artefacts afterwards.

In another study comparing physical and digital artwork, Quiroga, Dudley, and Binnie (2011) found that the original painting allowed for greater exploration of the entire canvas when compared to the digital copy shown in a laboratory setting, but they restricted the digital interactions to zooming in and out of the digital copy. Understandably, the two-dimensional nature of paintings does not allow for much more interaction. As opposed to interacting with a painting, the interactive elements of the digital modalities offered more options, which explains why the participants ranked all the modalities fairly high despite the older groups' preference for the physical artefacts. Moreover, the significant difference in time spent between the digital and physical modalities suggests that seeing artefacts first in the digital modalities allowed for more interaction, thus extending the amount of time with the artefacts. This follows the findings of Chang et al. (2014), which determined that using an AR guide extended the time spent viewing artwork in a museum. The significant time difference between the digital and physical modalities also may indicate that participants did not want to spend so much time viewing the physical artefacts since they had just interacted with the digital modalities. However, both digital modalities still produced a similar number of emotions as the physical artefacts despite participants spending more time with them.

A study conducted by Kamal Othman, Petrie, and Power (2011) focused on comparing physical museum experiences with and without the assistance of a multimedia mobile guide. Their results indicated that interaction with a mobile guide was more engaging than experiencing a museum without the mobile device. In contrast, the results in Chapter 6 established that not only were participants engaged when using personal devices, but the older adults enjoyed subsequently viewing the

physical artefacts more, even without the use of supplementary technology. While this study focused on age differences and Kamal Othman, Petrie, and Power's participants were various ages, the results suggest that using technologies to access museum artefacts outside a museum can offer engaging experiences that do not decrease the enjoyment of subsequently viewing the physical artefacts. Additionally, Kamal Othman, Petri, and Power found that the use of a multimedia mobile guide had no significant effect on emotional connections or meaningful experiences. This is similar to the results of Chapters 6 and 7, which also found no significant differences in emotional responses between the digital and physical modalities. However, the digital modalities did have a significant effect on the production on mental operations, and therefore also emotion, which was used to construct meaning. There may not have been such a significant difference if the physical artefacts were seen at a later time, not immediately after viewing the digital artefacts twice in two different modalities.

8.5.2. Interacting with digital artefacts online does not preclude a meaningful physical artefact experience

There is much concern about 'museum fatigue' and how museum visitors tend to lose interest in exhibits after a certain point due to various factors including cognitive processing and individual characteristics, especially if exhibits have similar objects (Bitgood 2009; Davey 2005). When users view digital museum artefacts online before seeing the physical artefact in a museum, this can lead to a similar effect, as the artefacts are the same and the digital artefacts have the added capability for interaction, which the physical artefacts do not. Although visitors were only presented with six options for artefacts, they viewed all six in the three modalities. 'Museum fatigue' may help to explain the significant difference between the digital modalities and the physical modality in the *Cognition* orientation and in 8 out of 12 mental operations: *Taking Note of*, *Identifying*, *Evoking*, *Anticipating*, *Comparing-Distinguishing*, *Grasping*, *Explaining-Justifying*, and *Verifying*, of which only *Comparing-Distinguishing* was higher in the physical modality compared to both digital modalities. Yet the participants' use of mental operations and orientations indicates that they were not passive when finally seeing the physical artefacts, and

meaning emerged from their interactions. Understandably, seeing these artefacts in person after first seeing the digital artefacts influenced participants to use *Comparing-Distinguishing* significantly more in the physical artefacts modality and the rest of the mental operations less.

'Museum fatigue' may not be an issue if visitors were not asked to interact with artefacts in both digital modalities or if there is a longer period of time between interacting with the digital artefacts and viewing them in person, as the participants in this study viewed three modalities consecutively. Still, after seeing the artefacts twice in the digital modalities, participants did not spend as much time using *Taking Note of* and *Identifying*, both belonging to the *Getting Acquainted with Objects* grouping category, in the physical modality. Instead, more effort was dedicated to the other three grouping categories. This signifies that participants were able to recognise the artefacts even though they were digitised and viewed under different conditions and viewpoints (Palmeri and Gauthier 2004), and they utilised other mental operations that did not focus on simply examining artefacts and becoming acquainted with them. Participants compared the physical artefacts to their digital representations by stating whether they saw something new or different. With each artefact modality, information was learned or confirmed, and most of the comparisons took place in the physical modality. Digital artefacts themselves can be considered 'tools for understanding the past' (Newell 2012), serving a similar purpose as labels in museums, which help visitors understand and interpret artefacts. This is suggested by the results of this study through the higher use of *Verifying* and *Explaining-Justifying*, since more time was spent asking questions about the digital artefacts (Dufresne-Tassé and Lefebvre 1994), and the higher use of *Grasping* and *Evoking*, which helped the participants understand the digital artefacts. Not surprisingly, *Anticipating* was used more often in the digital modalities because participants tried to understand the artefacts by predicting attributes of the physical artefacts such as height, weight, and texture. Labels have many purposes, among them are to highlight objects, provide answers, and 'elicit curiosity' (Screven 1992). Based on these functions, labels include text descriptions, audio, images, video, display techniques, and now 3D models of artefacts, as they too can be used for similar purposes.

Screven (1992) mentioned that a label's content can influence comparisons, and participants used the knowledge gained from the digital modalities in order to understand the artefacts in the physical modality, as evidenced by their high use of *Comparing-Distinguishing*. This can be beneficial for potential users of digital artefacts, since the information learned beforehand through interaction with the digital artefacts will give them a unique perspective for when they see the static, physical artefacts in the museum. They will have already seen the artefacts in different angles as well as up close, and seeing the artefacts in person will allow them to make comparisons and appreciate the artefacts within the museum setting. If visitors bring their mobile devices with them to the museum, they can interact with both the digital and physical artefact simultaneously, which can potentially lead to further understanding of artefacts. This supports the value of digital artefacts, not just physical artefacts, for creating meaning through learning, as Dufresne-Tassé and Lefebvre's (1994) framework was originally intended.

As mentioned above, digital artefacts can serve similar functions as labels since they can help understand an artefact, provide answers through interaction, and influence comparisons, but they still have their own labelling with titles and descriptions. These descriptions, while helpful, are usually limited, especially when compared to information that can be obtained in a museum through displays and museum guides. While Hume and Mills (2011) were concerned that displaying digital collections online might decrease the number of visitors to physical museums, the use of the *Anticipating*, *Verifying*, and *Explaining-Justifying* mental operations showed that participants were interested in aspects of the physical artefact that the digital artefacts or their descriptions did not provide or could not answer. Although some of these comments related to an artefact's size, participants also had questions about an artefact's history that could be promptly answered in a physical museum by guides or detailed descriptions. The results of this study shed some light onto Hume and Mill's uncertainty concerning the status of a museum collection's online presence by highlighting the importance of the physical museum visit to older and younger adults, even when they previously interacted with the digital artefacts.

8.6. Limitations

This study had a few limitations related to the experimental design of the modalities. One limitation is that even though the digital modalities were counterbalanced, asking participants to view six digital artefacts twice, and then see them all again in the physical modality, might have been overwhelming and could have resulted in the participants spending significantly less time in the physical modality. A similar study comparing two digital modalities and the physical artwork modality used different groups of participants for each modality, and it focused on the effect of different presentation conditions on art and non-art-trained users (Locher, Smith, and Smith 2001). Other studies that compared the same groups of participants only had two modalities to represent the physical and digital interactions (Lee, Luo, and Ou 2009; Terrenghi et al. 2007). Therefore, it is not clear whether seeing the same six artefacts in two digital modalities, or first interacting with the digital artefacts, along with the opportunities to see different angles, led to the significant decrease in time with the physical artefacts.

There was an expected learning curve for operating the tablet and even the laptop when using the mouse to interact with the artefacts. Both the older and younger participants experienced similar difficulties if they were not familiar with these technologies. Although the younger group most likely grew up with computers (Prensky 2001) and all have previously used smartphones or tablets (see Table 7), many participants, regardless of age, still took some time to get used to interacting with the artefacts using the tablet and mouse. Ultimately, all comments related to usability were not considered (see section 7.1.1), leaving only comments related to the artefacts. Still, while this could have affected the enjoyment and emotional responses to the artefacts in the digital modalities, participants were consistent in the number, valence, and arousal of emotions in each of the three modalities despite the younger group having a significantly higher familiarity with AR and the older group having visited more museums. As such, it can be assumed that if the technology influenced emotional responses, it was minimal. Additionally, in reality users will presumably interact with digital artefacts from their own personal devices. Users will most likely either already be familiar with how to interact with the devices or

have more time to become accustomed to the technology. Nevertheless, the results show that any struggles with adapting to the technology did not affect the enjoyment and emotions felt towards the artefacts.

This study used exploratory statistical analysis to highlight relationships between two age groups in three different modalities; it did not try to find any causal links. Due to the dependent variables used, especially from Dufresne-Tassé and Lefebvre's framework, many variables had to be tested. Therefore, some significant differences might have occurred due to chance. If causality is to be studied, a control group is needed, which this study did not use. Instead, this study is based on the methodologies of similar studies that statistically compared responses to digital and physical museum collections using ANOVA tests (Locher, Smith, and Smith 2001; Taylor 2001).

8.7. Conclusion

When older and younger adults interact with digital artefacts on personal devices, emotion and meaning occur. As emotion is a part of understanding artefacts and is linked to the construction of meaning, this is encouraging as any limitations with the technology or digital artefacts did not inhibit participants' abilities to interact with digital artefacts in the same way they would physical artefacts. This benefits people who may not be familiar with technology, those who want to visit museums but are unable to, and individuals who would rather access museum collections somewhere other than a museum. Additionally, digital artefacts can enable emotional connections and meaning even if viewers do not have any cultural connections to the artefacts and without any supplementary narratives; the viewer-artefact interaction was sufficient. Viewing physical artefacts afterwards also was not a passive experience, which is promising for both museum personnel and those who visit a museum after already interacting with digital artefacts online.

The next chapter considers this discussion in light of the research questions and provides conclusions and further research.

Chapter 9: Conclusions

With an increasing number of museums digitising their cultural heritage artefacts and making the 3D models accessible on websites and AR applications, more people may be able to interact with digital artefacts before seeing the physical artefacts in museums. Since this may be the first impression people have of the artefacts and the museum, it is essential to understand how interacting with digital artefacts outside of a museum enables emotional connections and meaning, both of which are considered important aspects of understanding museum artefacts (see sections 2.4 and 2.5).

Interacting with digital artefacts outside a museum requires the use of personal devices such as computers, tablets, and smartphones, and the potential audience may have a wide range of technology skills. Varying technology backgrounds could affect how users engage with digital artefacts, especially when the users represent older and younger adults, two age groups that traditionally have not only different technology skills, but who also represent distinct demographics of museum visitors. Despite these differences, there is relatively little research related to older and younger adults and how their interactions with digital artefacts can lead to emotions and meaning.

Previous chapters discussed the process of developing a study designed to contribute to existing knowledge about how older and younger adults interact with digitised artefacts outside of a museum, and their subsequent viewing of the physical artefacts. A preliminary study was conducted to understand how museum visitors emotionally connect with physical cultural heritage artefacts and the reasons for their emotions. Based on the themes identified, physical artefacts were selected, digitised, and implemented into two different digital modalities, a website on a laptop and an AR app on a tablet. The main study was conducted to understand how older and younger adults respond when first interacting with digital artefacts on two digital modalities, and afterwards, viewing the physical artefacts. The data were first analysed quantitatively, focusing on engagement based on time spent with the artefacts and emotional responses on questionnaires. Second, the data were analysed both

qualitatively and quantitatively, concentrating on participants' comments as they constructed meaning while interacting with artefacts. The results were then discussed according to the user-digital artefact interaction, age, and digital modalities, and the subsequent experience with the physical artefacts was explained.

9.1. Research questions addressed

Throughout the course of this thesis, three research questions were addressed. Chapters 3, 4, and 5 provided the methodologies needed to address the questions; thus, they will be acknowledged as a preface to the research questions. Chapters 3 and 4 first explained the methodologies behind selecting, digitising, and implementing the digital artefacts for the modalities. Chapter 5 then provided the methodology for showing the three artefact modalities to older and younger adults.

1. How do older and younger adults emotionally respond to digital cultural heritage artefacts outside of a museum?

   Chapter 6 addressed this question through the quantitative analysis of the time spent within each digital modality and responses on questionnaires, which asked participants to indicate their enjoyment and emotions felt in response to interacting with the digital artefacts. There was no significant difference between the older and younger adults in both digital modalities and engagement based on the time spent with artefacts, and both age groups highly enjoyed the digital modalities. Additionally, there was also no significant difference between the digital modalities and emotional connections made by both age groups through their emotion counts, S_1 and S_2 values, and *Emotion* orientation. The results suggest that despite significant differences in the number of past physical museum visits and familiarity with AR technologies, older and younger adults enjoyed both digital modalities and were able to emotionally connect with digital artefacts presented in two different modalities through emotions with similar valences and intensities. Chapter 8 discussed the implications of these results, including how emotional responses to digital artefacts can benefit older and younger adults' museum experiences, and provided further examples of the

emotional connections made by participants. Despite differences in their technology backgrounds, older and younger adults have similar goals when visiting museums, including making emotional connections through reminiscing or learning, and the digital modalities' controls supported their individuality. While younger people are more familiar with current technologies, older people use technology to support their health and well-being. As the modalities enabled older people to access artefacts associated with a museum, a place they often visit in their free time, they were able to accept digital artefacts as museum objects and emotionally connect with them.

2. How do older and younger adults construct meaning while interacting with digital cultural heritage artefacts outside of a museum?

   Chapter 7 addressed this question through qualitative and quantitative analyses. Through the think-aloud method and implementation of the framework by Dufresne-Tassé and Lefebvre, insight was provided as to how older and younger adults construct meaning while interacting with digital artefacts. The results indicated that in the 3D models on a laptop modality, older adults used 4 out of 12 mental operations significantly higher than the younger group, while the younger group used a significantly higher number of *Comparing-Distinguishing* mental operations, yet both age groups were not passive in the digital modalities. As the modalities changed, there was only a significant difference between the two digital modalities in 1 out of 12 mental operations, which showed that meaning emerged from interactions with artefacts on the website and AR app. As this was the only significant difference between the AR on a tablet and 3D models on a laptop modalities, the grouping categories were also not significantly affected by the change in modality. Chapter 8 discussed the implications of these results, particularly reviewing how meaningful interactions with digital artefacts can occur despite participants having no cultural connections with the artefacts, the lack of detailed descriptions and display methods, and any limitations with the quality or realism of the digital artefacts. As older people use technology such as the Internet and mobile devices to access information and become more independent, they are becoming more technology-

savvy. This enabled meaning to emerge from their interactions with digital artefacts in both digital modalities, in addition to their past museum experiences and expectations for reminiscence in museums. Similarly, young adults were able to construct meaning while interacting with digital artefacts on modalities they already use in their daily lives, and they had the freedom to control their own engagement through the way they interacted with artefacts.

3. How does first interacting with the digital cultural heritage artefacts outside of a museum affect the subsequent viewing of the physical artefacts?

   Chapters 6 and 7 addressed this question through the quantitative and qualitative analyses. The time spent, number of mental operations, and the *Cognition* orientation significantly decreased in the physical artefacts modality, yet emotion counts, S_1 and S_2 values, and the *Emotion* orientation remained the same. Moreover, the older adults significantly enjoyed the physical artefacts more than the digital artefacts compared to the younger adults, and both age groups highly enjoyed all three modalities based on their rankings. These results signified that viewing the physical artefacts after first seeing the artefacts in two different digital modalities still enabled the participants to make emotional connections and meaning, and the older group's enjoyment increased, demonstrating that the digital modalities can be a complementary experience to viewing physical artefacts. Chapter 8 discussed the effects of these results, focusing on how the digital modalities can be used as a supplementary experience to the physical museum and the value of the physical artefacts experience.

9.2. Contributions

By answering the research questions, this thesis has contributed to existing knowledge in a number of ways, which will help museum practitioners, cultural heritage researchers, and HCI researchers.

By addressing the first and second research questions, this study contributes an understanding of how older and younger adults make emotional connections and meaning when first interacting with 3D models of cultural heritage artefacts. Previous research, specifically section 2.4, discussed visitor's emotional responses to physical museum objects inside a museum (Damala et al. 2013; Gadsby 2011; Silvia 2005; Locher, Smith, and Smith 2001), and section 2.2 mentioned technologies for encouraging visitors to personalise their visit by reflecting or contributing emotional responses to exhibits (Cosley et al. 2008; Boehner, Sengers, and Gay 2005; Boehner et al. 2005), but few studies concentrated on emotion or meaning when interacting with different types of digital cultural heritage artefacts outside the museum. This is a timely concern as users' experiences on museums' websites can encourage them to visit the museum and inform others of what they have seen through social media, blogs, and word of mouth. Additionally, previous research indicated that older and younger people are seeking emotional connections and meaningful experiences in museums. The opportunities for these experiences increase when they interact with 3D models of artefacts either on websites or AR apps from the convenience of personal devices. As Section 2.2 demonstrated, world-renowned museums are currently making their collections available online through their websites and AR apps, increasing the need to understand how users make emotional connections and meaning with these types of digitised artefacts outside the museum. This study provides some insight into this type of interaction, which can contribute to existing knowledge about museum artefacts and how they encourage emotion and meaning.

Studies that previously investigated interactions with digital cultural heritage artefacts did not compare distinct age groups such as older and younger adults (Hogsden and Poulter 2012b; Hess et al. 2011), despite both studies involving interactive digital artefacts on websites. Furthermore, emotion or meaning was not the motivation of both studies; instead, these studies focused on concerns with repatriation and reconnecting artefacts with local communities. Section 2.1 discussed how older and younger adults are two diverse age groups, both in how they view museums and their technology knowledge and skills, yet they both want enjoyable museum experiences. The availability of interactive digital artefacts outside of a museum can enable both groups to experience museum artefacts

according to their needs. This was demonstrated through the results of Chapters 6 and 7 and the discussion in Chapter 8, as both age groups enjoyed interacting with digital artefacts as well as felt emotions and constructed meaning during their interactions. Accordingly, it is recommended that both digital modalities, the 3D models shown on a website and the AR app on a mobile device, can be potentially used by older and younger adults and anyone else, no matter the technology background, to interact with museum artefacts. Sections 8.2.1 and 8.3.1 provided some examples of how these technologies meet both their museum needs and goals. Therefore, the comparison of older and younger adults in the context of digitised artefacts is one that needs more attention in cultural heritage artefact studies, a topic addressed by this study.

By addressing the third research question, this study contributes by providing insight into how users can still feel emotions and make meaning from interactions with physical artefacts after first interacting with the digital ones. Previous research used different groups of participants to explore how they viewed and rated original and digital artwork (Quiroga, Dudley, and Binnie 2011; Locher, Smith, and Smith 2001), but in both these cases, participants saw the original artwork in the museum, while the digital copies were shown in either a non-gallery room, which influenced their responses. Taylor (2001) used the same groups of participants for both digital and physical artworks, but again, participants viewed the original inside a museum and the digital copies in an office-setting. To date, there are few studies comparing how the same participant feels emotions and constructs meaning when first interacting with the digital artefacts, then the physical artefacts. This study extends the knowledge gained from museum studies comparing physical and digital modalities by using the same participants and consistent conditions for all modalities, as well as focusing on 3D models of artefacts. The motivation for this is related to the availability of digital artefacts on museum websites, since it enables the interaction of digital artefacts before viewing the physical artefacts in museums. It is essential to understand how this affects the same person, as the digital artefacts are also part of a museum's collection and may influence a physical visit. Chapters 6 and 7 indicated that both older and younger adults still found the physical artefacts enjoyable even after seeing the digital artefacts first. They also emotionally

connected with the physical artefacts and found them meaningful. Based on this, digital artefacts can be used both as a compelling method of viewing artefacts and as a complement to a physical visit.

The methodology used in this study, including Dufrese-Tassé and Lefebvre's (1994) framework supported with questionnaires and the think-aloud method, and its focus on older and younger adults, has contributed to an understanding of how diverse age groups' interactions with digitised 3D museum artefacts can lead to emotion and meaningful experiences. Dufresne-Tassé and Lefebvre evaluated their framework in various physical museums, including a natural history museum, a fine arts museum, a museum of history and ethnology, and a museum of natural sciences. Subsequent studies utilising Dufresne-Tassé and Lefebvre's framework were conducted in architectural exhibitions (Laberge 2010) and referred to when evaluating visitors' experiences at a science museum (Mortensen 2011), both pertaining to the physical museum experience. This study contributes to the understanding of the in-situ experience of viewing museum objects by applying the framework to viewing digital cultural heritage artefacts in two digital modalities, a website and an AR app. The results of Chapters 6 and 7 indicated that older and younger adults were able to utilise the mental operations and orientations in Dufresne-Tassé and Lefebvre's framework to feel emotions and construct meaning in response to digitised museum artefacts. Therefore, diverse audiences have the opportunity to experience emotion and meaning while viewing and interacting with digital museum artefacts using their own devices and without stepping foot inside a physical museum. Relatedly, this study extends research on digital museum technologies that provide a valuable online and standalone museum experience (Arts Council 2013, Brown 2005). Diverse audiences with different educational backgrounds and skills have a degree of freedom over how they access digital artefacts and information online, and as a result, they can have different online experiences each time they visit.

9.3. Future work

Due to advancing technologies and the vast research opportunities museums provide, this study only concentrates on a small cross-section of HCI and museums. As such,

future work can address the limitations of this study as well as emphasise different technologies and museum concerns.

One limitation was that although older and younger adults all had varying degrees of familiarity with 3D models and AR technology, there was still a learning curve to become accustomed to interacting with the artefacts. This study required participants to use the same laptop and tablet to interact with the artefacts, but in reality, people will access artefacts using their own devices and therefore, they would have a proper amount of time to become accustomed with a device's functionalities for interacting with an artefact. Correspondingly, future research can investigate how older and younger adults interact with digital artefacts using their own devices, thus reducing the need for participants to become accustomed to the devices and interaction methods. Rather than conduct the study in a pre-arranged setting, researchers might observe how users interact with digital artefacts on mobile devices while on-the-go. This would be particularly interesting for the AR modality, as users can take mobile devices anywhere and move the image targets anyplace in the physical world.

Additionally, participants were presented with the same six artefacts in all three modalities. As the study required that emotion and meaning were compared between the digital modalities and then with the subsequent physical modality, it was necessary that the artefacts shown were consistent throughout the study. However, separate groups of participants might be used if more than one digital modality is compared. As one modality is mobile and one is more of a desktop modality, users might access digital artefacts on these two devices for different reasons. If participants are using their own devices, there will be a broad range of screen sizes, and any connections between artefacts viewed on different screen sizes and emotion and meaning may be examined. After users interact with the digital artefacts, their emotional connections and construction of meaning can be compared to when they view the physical artefacts, especially with regards to the time spent in each modality.

Another aspect of this study that could better emulate real life is to understand how participants view the physical artefacts inside a museum. This study specifically

maintained the same conditions for all three modalities for consistency when comparing responses, but future research could be carried out to see how visitors emotionally respond to physical artefacts exhibited in a museum after first interacting with the digital artefacts on their own personal devices. Afterwards, it could also be useful to determine if interacting with the digital artefacts alongside the physical artefacts enhances the overall museum visit.

Since this study was dedicated to digital artefacts and how users' interactions with them can lead to emotion and meaning, only the first two aspects of Dufresne-Tassé and Lefebvre's (1994) framework were investigated fully. Their third aspect, direction of attention, was utilised to classify comments according to what a participant was referring to, and the fourth aspect, form of operation, was used to categorise actions such as zooming and rotating and filter out any comments related to usability. However, it was the first two aspects, mental operations and orientation that provided the most insight into how meaning is given to artefacts. Future work might investigate interactions with digital artefacts using all four aspects of the framework to gain a broader understanding of participants' overall experience as they interact with artefacts.

The interactive museum experience as discussed by Falk and Dierking (1992d) was briefly mentioned in section 2.3.1 to explain the physical context of a museum. Falk and Dierking's subsequent inclusion of digital and online technologies to the museum experience discussed websites and social media, but not digitised artefacts and visitors' interactions with them (Falk and Dierking 2012). The use of personal devices outside of a museum to interact with digital artefacts could be studied according to all three of their museum contexts: physical, personal, and social. The physical context would refer to the museum website that visitors access to interact with the artefacts or download an app, the personal context would still apply to the visitor's background and motivations, and sharing these experiences online through social media or reviews would define the social context. By providing some insight into how meaning emerges from older and younger participants' interactions with digital artefacts, this study alluded to the personal context, but it did not delve into learning or a person's background, culture, or motivations for viewing artefacts. In

addition, section 8.4 briefly mentioned the collaborative forms of engagement enabled by digital artefacts, including contributions from end-users, but future work could examine this as part of the social context. Museum visitors and professionals can benefit from this knowledge because even though the artefacts are outside a museum, visitors' goals and motivations for visiting a museum could still be met.

With regards to new technology, future work can explore older and younger adults' emotional and meaningful experiences using haptics. Recent research explored the ability to 'touch' virtual artefacts, which provides a novel aspect of interacting with artefacts (Osorio et al. 2011; Figueroa, Londoño, et al. 2009), and this can further influence users' emotional and meaningful experiences. For older people whose vision is impaired, haptics can provide them with a way of interacting with digital artefacts when they are unable to travel to a museum. Museum artefacts have also been used for therapy for older or disabled people (Smiraglia 2015; Chatterjee and Noble 2009; Chatterjee, Vreeland, and Noble 2009), but if museums are unable to loan their physical artefacts, perhaps their digital, haptic representations can replace them.

As advanced technologies become available to users outside the museum, they become a valuable option for experiencing museum artefacts. Both older and younger adults have expressed a need for experiencing emotional connections to museum collections and meaning, yet their circumstances may not allow for frequent visits to the physical museum. When users access digital artefacts using their own personal devices, they can benefit by having a comfortable, enjoyable experience at their own convenience. The study demonstrates that interacting with digital artefacts using personal devices can lead to emotional connections and meaning; however, future research can investigate whether making digital artefacts accessible online either decreases interest in visiting a physical museum or results in significantly less time spent viewing the artefacts in a museum, with and without the use of their personal devices. A greater focus on this issue can lead to awareness of differences in digital and physical artefact needs of museum visitors, especially in studies where participants access the artefacts using their own devices.

The work carried out in this study contributes to the growing need to understand the effects of digitising cultural heritage artefacts and making them accessible online. While advantages of digital cultural heritage artefacts include preservation and distribution to different audiences, researchers are still discovering their potential benefits. When a viewer is able to emotionally connect with digital museum artefacts and give them meaning, it can have positive effects in many different aspects of life, including health and well-being, education, and leisure. Older and younger adults in particular have shown that having a technology background is not crucial to making emotional connections or meaning from interactions with digital artefacts, and these connections can be made regardless of modality. Nevertheless, this study has shown that viewing physical artefacts is still valued by participants. Additionally, when digital artefacts are viewed before the physical artefact, they can provide a supplementary experience to the physical museum visit. By focusing on emotions and meaning, this study hopefully has provided insight into important aspects of the viewer-artefact interaction, including responses to digital artefacts implemented in personal and mobile devices and the subsequent experience of viewing the physical artefacts, all of which can be applied to users of various technology backgrounds.

Appendix A: Emotional Response Log

University of Kent

Canterbury, Kent, UK

Emotional Response Log

Powell-Cotton Museum

Date: _____

Participant #1

Please return your completed Emotional Response Log to the researcher at the entrance to the first artefacts room

Thank you for agreeing to participate in our research study today. This project is being conducted by a PhD student at the School of Engineering and Digital Arts, University of Kent, where we are exploring innovative ways of using technology to enhance museum visitors' experience.

In this pilot study we are interested in finding out how museum visitors engage emotionally with the artefacts. It would be very helpful if you could provide your responses to the museum artefacts in the space provided on the following sheets.

Gallery Name:

Artefact Name (if no name, please describe):

How does this artefact make you feel? Please circle 1 response from the following choices or write-in your own in the blank space after "Other":

Anger	**Disgust**	**Fear**	**Happy**
Sad	**Surprise**	**Indifferent**	**Other:** _____

Additional Comments:

Gallery Name:

Artefact Name (if no name, please describe):

How does this artefact make you feel? Please circle 1 response from the following choices or write-in your own in the blank space after "Other":

Anger	**Disgust**	**Fear**	**Happy**
Sad	**Surprise**	**Indifferent**	**Other:** ______________

Additional Comments:

Gallery Name:

Artefact Name (if no name, please describe):

How does this artefact make you feel? Please circle 1 response from the following choices or write-in your own in the blank space after "Other":

Anger	**Disgust**	**Fear**	**Happy**
Sad	**Surprise**	**Indifferent**	**Other:** ______________

Additional Comments:

Gallery Name:

Artefact Name (if no name, please describe):

How does this artefact make you feel? Please circle 1 response from the following choices or write-in your own in the blank space after "Other":

Anger	**Disgust**	**Fear**	**Happy**
Sad	**Surprise**	**Indifferent**	**Other:** ______________

Additional Comments:

Gallery Name:

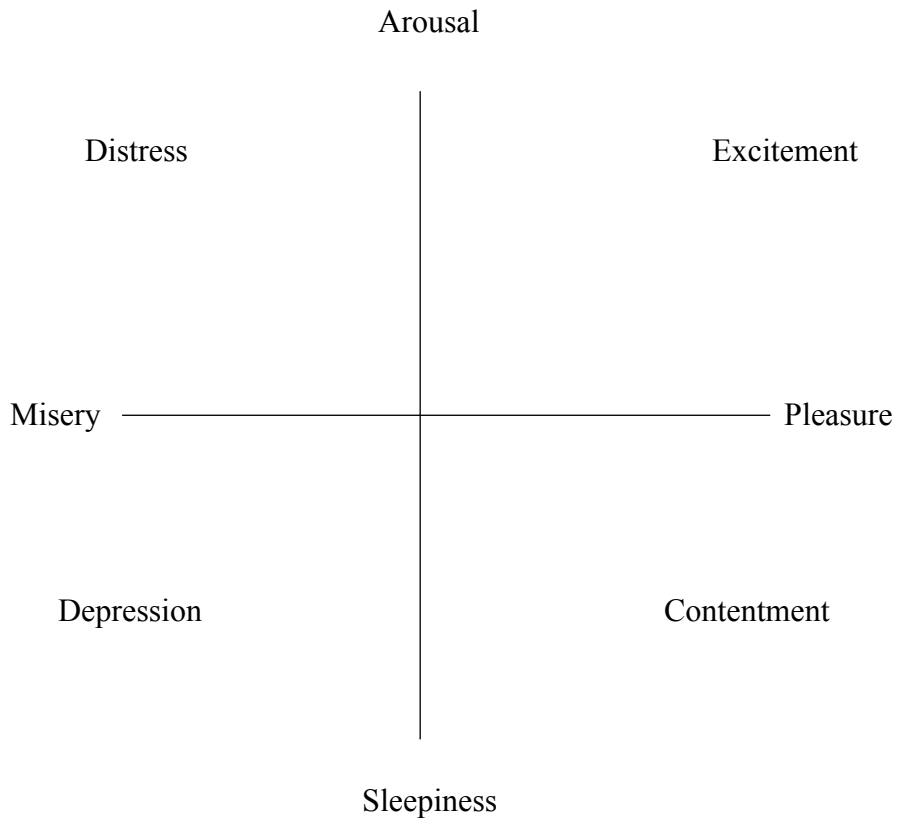
Artefact Name (if no name, please describe):

How does this artefact make you feel? Please circle 1 response from the following choices or write-in your own in the blank space after "Other":

Anger	**Disgust**	**Fear**	**Happy**
Sad	**Surprise**	**Indifferent**	**Other:** ______________

Additional Comments:

Appendix B: Russell's Circumplex Model of Affect



source: Russell 1980

Appendix C: Preliminary Study Consent Form

Participant #___

Dear Participant,

Thank you for your interest in our research study where we are finding out how museum visitors engage emotionally with the artefacts. This form describes what you will be asked to do for the study. If you have questions, please feel free to contact the Lead Researcher whose details are listed at the bottom of this sheet.

We would like you to participate in the following two aspects of this study:

1) The Emotional Response Log which will be provided to you – please write down your initial emotional responses to the museum artefacts which you feel the strongest response to

2) The post-study interview which will take between 20-30 minutes – the researcher will ask you additional questions related to your emotional responses to artefacts in the Emotional Response Log. This interview's audio will be recorded.

Confidentiality:

All written information will be kept in a secure location and the audio recording will be stored in an internal, secured password protected network and kept separate from information about your identity. Access to your data is limited to the researchers carrying out this study. Any use of the recordings will be completely anonymous.

Please note that you are helping the researchers gain information into how visitors engage emotionally with artefacts – there are therefore no right or wrong answers to the questions you will be asked.

The researchers are very grateful for your help.

Please sign and date two copies of this Consent Form, keeping one copy for yourself for your records, to indicate:

____ I agree to audio recordings for the purposes stated above

____ I do not agree to audio recordings

_____ _____ _____

Name of Participant Date Signature

_____ _____ _____

Name of person taking consent Date Signature
(if different from lead researcher)
To be signed and dated in presence of the participant

_____ _____ _____

Lead Researcher Date
Signature

Researcher contact information: Genevieve Alelis • ga209@kent.ac.uk
School of Engineering and Digital Arts, University of Kent, Canterbury, Kent, CT2 7NT

Appendix D: Preliminary Study Questionnaire

Participant #___

Please tell us about yourself:

1. With whom are you visiting?

□ Solo □ Family and Children □ Family (All Adults)
□ Friends □ Friends and Family □ Other_____

2. Please indicate your gender:

□ Female □ Male

3. What is your age group?

□ 18-24 □ 25-34 □ 35-44 □ 45-54 □ 55-64 □65+

4. In the last 12 months, how many times did you visit any museum? *Please circle your answer*

0 1 2 3 4 > 5 Do not remember

5. In the last 12 months, how many times did you visit the Powell-Cotton Museum? *Please circle your answer*

0 1 2 3 4 > 5 Do not remember

6. What is the reason for your visit today?

□ Leisure □ Educational □ Other (please specify)_____

7. Where have you travelled from to visit the Powell-Cotton Museum?

□ Kent □ Elsewhere Within the UK □ Overseas □ Other (please specify)_____

8. Which of the following categories best describes your race/ethnicity?

□ Non-Hispanic White

□ Hispanic/Latino

□ African-American

□ Native American

□ Asian/Pacific Islander

□ Multiracial

□ Other_____

9. Do you have access to a smartphone?

□ Yes □ No

10. If "Yes", what type(s) of smartphone? *(For example, iPhone, Blackberry, Android, etc.)*

_____

Appendix E: Preliminary Study Interview Questions

Participant #___

- *These questions will be asked after the researcher reads the visitor's answers in the Emotional Response Log*
- *The visitor will be completing the questionnaire during this time.*
- *The numbers match the corresponding order of the artefact chosen in the Emotional Log*

1. Describe how you felt when you saw (name of artefact/gallery).

2. Can you tell me why this artefact made you feel this way (past events, life experience, memory, knowledge)? Please explain in some detail.

3. How strongly were you affected positively, negatively, or neutrally?

4. Can you tell me why *(name of artefact/gallery)* interested you more than the others?

5. Did you read the exhibit label and if so, how did it affect your response?

Appendix F: Main Study Consent Form

Participant #___

Dear Participant,

Thank you for your interest in our research study where we are finding out how individuals engage with physical and digital artefacts from a museum. This form describes what you will be asked to do for the study. Please read through it and then sign at the bottom to indicate that you understand and accept the conditions of this study.

If you have questions, please feel free to contact the researcher whose details are listed at the bottom of this sheet.

We would like you to participate in the following two aspects of this study:

1) Viewing and interacting with physical and digital artefacts in which you will be asked to verbalise all responses and interactions which will take about 40 minutes

2) An interview which will take between 10-15 minutes - you will be asked additional questions related to your interactions and responses

The entire study will be videotaped in order to capture all data.

Please note that you are helping the researchers gain information into how individuals engage with different formats of artefacts – therefore there are no right or wrong answers to the questions you will be asked.

Your participation in this study is voluntary and you can leave the study at any time without penalty or giving reasons.

Confidentiality:

All information, both written and digital, will be anonymous and be kept separate from information about your identity in a secure location in an internal, secured password protected network. Access to your data is limited to the researchers carrying out this study. The results may be published and any use of the data and video recordings will be completely anonymous.

The researchers are very grateful for your help.

Please select one of the options below and then sign and date this Consent Form to indicate that you understand and accept the conditions of this study.

____ I understand the purpose of this study and agree to video recordings for the purposes stated above

____ I do not agree to video recordings

_____	_____	_____
Name of Participant	Date	Signature
_____	_____	_____
Name of Researcher	Date	Signature

To be signed and dated in presence of the participant

Contact: Genevieve Alelis (ga209@kent.ac.uk)
Researchers: Genevieve Alelis, Ania Bobrowicz, Dr. Jim Ang
School of Engineering and Digital Arts, University of Kent, Canterbury, Kent, CT2 7NT

Appendix G: Main Study Demographic Questionnaire

Older Participant Questionnaire

Participant #___
Please tell us about yourself:

1. Please indicate your gender: □ Female □ Male
2. Please state your age: _____
3. Which of the following categories best represents your ethnic group? *Please tick one*

White:
□ English / Welsh / Scottish / Northern Irish / British
□ Irish
□ Other White_____

Mixed:
□ Mixed White & Black Caribbean
□ Mixed: White & Black African
□ Mixed: White & Asian
□ Other Mixed_____

Asian:
□ Indian
□ Pakistani
□ Bangladeshi
□ Chinese
□ Other Asian_____

Black/African/Caribbean:
□ African
□ Caribbean
□ Other Black_____

□ Other ethnic group_____

4. What is the highest level of education you have completed? Please tick every box that applies

□ O levels/CSEs/GCSEs, or equivalent

□ A levels, or equivalent

□ Degree (for example BA, BSc)

□ Higher degree (for example MA, MSc, PhD)

□ Professional qualifications (for example teaching, nursing, accountancy)

□ Other vocational/work-related (for example BTEC, NVQ)

□ Foreign qualifications

□ No qualifications

5. Please rate your familiarity with 3D virtual objects: Please circle one number

0 1 2 3 4 5
Never Heard of It Very Familiar

6. Please rate your familiarity with augmented reality: Please circle one number

0 1 2 3 4 5
Never Heard of It Very Familiar

7. In the last 12 months, how many times did you visit any museums/galleries/etc? Please circle your answer

0 1 2 3 4 >5 Do not remember

8. How many times have you viewed a museum's collection online? Please circle your answer

0 1 2 3 4 >5 Do not remember

9. Have you ever used a smartphone or tablet? □ Yes □ No

10. If "Yes", what type(s)? Please circle your answer(s)
iPhone Blackberry Android iPad Other_____ I don't know

Younger Participant Questionnaire

Participant #___
Please tell us about yourself:

2. Please indicate your gender: □ Female □ Male
2. Please state your age: _____
3. Which of the following categories best represents your ethnic group? *Please tick one*

White:
□ English / Welsh / Scottish / Northern Irish / British
□ Irish
□ Other White_____

Mixed:
□ Mixed White & Black Caribbean
□ Mixed: White & Black African
□ Mixed: White & Asian
□ Other Mixed_____

Asian:
□ Indian
□ Pakistani
□ Bangladeshi
□ Chinese
□ Other Asian_____

Black/African/Caribbean:
□ African
□ Caribbean
□ Other Black_____

□ Other ethnic group_____

4. Please state your degree_____ and course of study: _____

5. Please rate your familiarity with 3D virtual objects: Please circle one number

0 1 2 3 4 5
Never Heard of It Very Familiar

6. Please rate your familiarity with augmented reality: Please circle one number

0 1 2 3 4 5
Never Heard of It Very Familiar

7. In the last 12 months, how many times did you visit any museums/galleries/etc? Please circle your answer

0 1 2 3 4 >5 Do not remember

8. How many times have you viewed a museum's collection online? Please circle your answer

0 1 2 3 4 >5 Do not remember

9. Have you ever used a smartphone or tablet? □ Yes □ No

10. If "Yes", what type(s)? Please circle your answer(s)
iPhone Blackberry Android iPad Other_____ I don't know

Appendix H: Main Study Artefact Questionnaire

Participant #___

Augmented Reality Artefacts Questionnaire

Please rate your experience:

1. How enjoyable was this experience? Please circle your answer

1	2	3	4	5	6	7	8	9	10
Low									High

2. Which artefact(s) made you feel the following emotions:

Anger_____

Disgust_____

Fear_____

Happiness_____

Sadness_____

Surprise_____

Indifferent_____

Other_____

3. Which artefact did you like most and why?

_____

_____

_____

_____

4. Which artefact did you like least and why?

_____

_____

_____

_____

Participant #___

3D Artefacts Questionnaire

Please rate your experience:

1. How enjoyable was this experience? Please circle your answer

1	2	3	4	5	6	7	8	9	10
Low									High

2. Which artefact(s) made you feel the following emotions:

Anger_____

Disgust_____

Fear_____

Happiness_____

Sadness_____

Surprise_____

Indifferent_____

Other_____

3. Which artefact did you like most and why?

_____

_____

_____

_____

4. Which artefact did you like least and why?

_____

_____

_____

_____

Participant #___

Physical Artefacts Questionnaire

Please rate your experience:

1. How enjoyable was this experience? Please circle your answer

1	2	3	4	5	6	7	8	9	10
Low									High

2. Which artefact(s) made you feel the following emotions:

Anger_____

Disgust_____

Fear_____

Happiness_____

Sadness_____

Surprise_____

Indifferent_____

Other_____

3. Which artefact did you like most and why?

_____

_____

_____

_____

4. Which artefact did you like least and why?

_____

_____

_____

_____

Appendix I: Emotional Intelligence Questionnaire

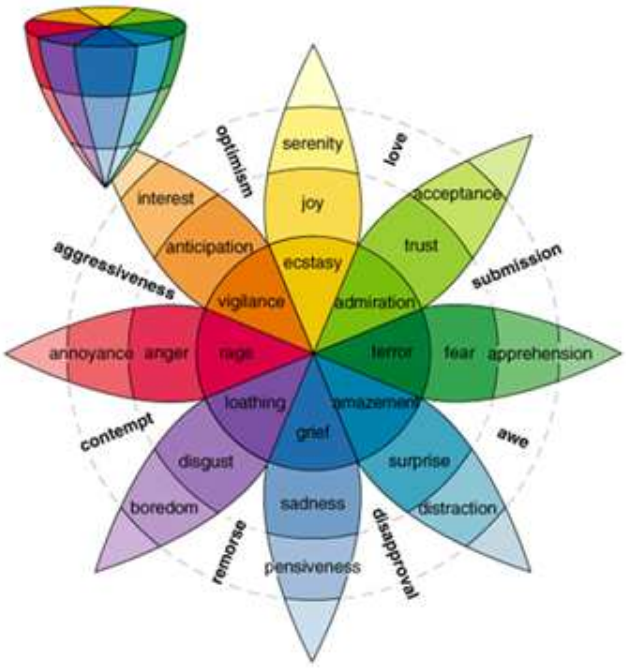
Participant #___
Instructions: Indicate the extent to which each item applies to you using the following scale:

1	2	3	4	5
strongly disagree	disagree	neither disagree nor agree	agree	strongly agree

_____ 1. I know when to speak about my personal problems to others
_____ 2. When I am faced with obstacles, I remember times I faced similar obstacles and overcame them
_____ 3. I expect that I will do well on most things I try
_____ 4. Other people find it easy to confide in me
_____ 5. I find it hard to understand the nonverbal messages of other people
_____ 6. Some of the major events of my life have led me to re-evaluate what is important and not important
_____ 7. When my mood changes, I see new possibilities
_____ 8. Emotions are one of the things that make my life worth living
_____ 9. I am aware of my emotions as I experience them
_____ 10. I expect good things to happen
_____ 11. I like to share my emotions with others
_____ 12. When I experience a positive emotion, I know how to make it last
_____ 13. I arrange events others enjoy
_____ 14. I seek out activities that make me happy
_____ 15. I am aware of the nonverbal messages I send to others
_____ 16. I present myself in a way that makes a good impression on others
_____ 17. When I am in a positive mood, solving problems is easy for me
_____ 18. By looking at their facial expressions, I recognize the emotions people are experiencing
_____ 19. I know why my emotions change
_____ 20. When I am in a positive mood, I am able to come up with new ideas
_____ 21. I have control over my emotions
_____ 22. I easily recognize my emotions as I experience them
_____ 23. I motivate myself by imagining a good outcome to tasks I take on
_____ 24. I compliment others when they have done something well
_____ 25. I am aware of the nonverbal messages other people send
_____ 26. When another person tells me about an important event in his or her life, I almost feel as though I have experienced this event myself
_____ 27. When I feel a change in emotions, I tend to come up with new ideas
_____ 28. When I am faced with a challenge, I give up because I believe I will fail
_____ 29. I know what other people are feeling just by looking at them
_____ 30. I help other people feel better when they are down
_____ 31. I use good moods to help myself keep trying in the face of obstacles
_____ 32. I can tell how people are feeling by listening to the tone of their voice
_____ 33. It is difficult for me to understand why people feel the way they do

source: Schutte et al. 1998

Appendix J: Plutchik's Three-Dimensional Circumplex Model of Affect



source: Plutchik 2001

Appendix K: Main Study Urls for Website and Files for Creating the 3D Models and AR App

1. https://sites.google.com/site/gcadigitalartefacts/
   a. Website used in the 3D models on a website modality

2. https://www.dropbox.com/sh/qtrbqn0erp633vr/AADQ4lvMUb9knqT_JDyh-peka?dl=0
   a. Unity files used to create the AR app
   b. Image targets for each artefact
   c. Files used for the 3D models of artefacts

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