Comparison of engagement and emotional responses of older and younger adults interacting with 3D cultural heritage artefacts on personal devices

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The availability of advanced software and less expensive hardware allows museums to preserve and share artefacts digitally. As a result, museums are frequently making their collections accessible online as interactive, 3D models. This could lead to the unique situation of viewing the digital artefact before the physical artefact. Experiencing artefacts digitally outside of the museum on personal devices may affect the user's ability to emotionally connect to the artefacts. This study examines how two target populations of young adults (18-21 years) and the elderly (65 years and older) responded to seeing cultural heritage artefacts in three different modalities: augmented reality on a tablet, 3D models on a laptop, and then physical artefacts. Specifically, the time spent, enjoyment, and emotional responses were analysed. Results revealed that regardless of age, the digital modalities were enjoyable and encouraged emotional responses. Seeing the physical artefacts after the digital ones did not lessen their enjoyment or emotions felt. These findings aim to provide insight into the effectiveness of 3D artefacts viewed on personal devices and artefacts shown outside of the museum for encouraging emotional responses from older and younger people.

Keywords: augmented reality, 3D, elderly people, young adults, emotion, cultural heritage museum artefacts

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1. Introduction

Museums are increasingly offering new methods of engaging and educating visitors through the use of Human-Computer Interaction (HCI) systems. These are available both inside and outside the museum through mobile guides, interactive exhibits, downloadable games, and 3D artefacts. While there has been recent research into their impact and effectiveness (Bautista 2013; Tallon and Walker 2008), few have reported on 3D artefacts viewed on devices capable of being used outside of a museum and their effects on emotional responses to artefacts. Gradually, museums are also creating augmented reality (AR) apps, which can be downloaded onto personal mobile devices for users to view artefacts in situ in the museum. However, it was found that digital modalities used while viewing artwork can be distracting and may interfere with the museum visit (Damala et al. 2008). It is becoming more frequent for museums to put digitised versions of their artefacts online for viewing outside of the museum, but usually as images on their websites. Interactive 3D models of artefacts have only recently been made available online on museum websites, which can be accessed at any time using personal devices at home such as computers or on the go through tablets or smartphones. However, no matter how potential users access these artefacts, they should be considered as part of a museum's collection and therefore produce similar responses. Museum objects enable visitors to remember the past and make connections, which leads to feeling emotions, an important aspect of the museum experience. The value of emotional experiences in museums has been linked to trust, resulting in repeat visits and donations (Suchy 2006), which are essential to a museum. Past studies show that seeing artwork that is authentic or original influences these emotional responses. However, it was also found that the museum environment and display methods may have contributed to these emotions (Gadsby 2011; Locher et al. 2001; Taylor 2001).

Previous research showed that when artefacts are removed from a museum and its “reverential environment” (Hooper-Greenhill 1999), they are still capable of provoking emotions (Chatterjee and Noble 2009). 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. In these cases, preserving artefacts and making them available to a wider audience are important measures that should be considered (Styliani et al. 2009). 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, we believe that museum artefacts could benefit from digital representations, but there needs to be a greater understanding of how users engage with and emotionally respond to the 3D artefacts viewed on different devices before they have seen the physical artefacts.

In general, the two groups that have different technology backgrounds and therefore may have the most distinctive responses to the digitised artefacts are younger (ages 18-21) and older (ages 65+) people. A comparison of younger and older people’s experiences is lacking in the area of digital technologies and cultural heritage studies, especially when the technology used is transparent. Cameron (2007) discussed how digital historial objects can prompt emotional responses, but emphasised that the technology used should remain invisible to the user. When technology is transparent, the users may have different skills, which can affect their responses. Still, there are potential benefits of digital artefacts: younger people can access and share museum collections on the go, while older people would be able to view artefacts at a more leisurely pace. Therefore, the purpose of this study is to explore these two groups’ responses to museum artefacts in three different modalities, two of which are digital: 3D models on a website that are shown on a laptop (which will be referred to as 3D models on a laptop) and an AR app shown on a tablet (referred to as AR on a tablet).

Two distinct ways museums present their digitised artefacts are as images on websites or as AR apps for mobile devices. Due to new technologies, 3D models can now be considered; therefore, 3D models on a website and in an AR app are the two digital modalities that will be addressed. In addition, the following will also be assessed: participants' time spent within each modality, their enjoyment of the modalities, and their emotional responses within each modality. The results will provide a better understanding of whether 3D artefacts are capable of creating emotional and engaging experiences, which can ensure that digital artefacts can be used to extend the museum experience beyond any boundaries.

The structure of this paper is as follows: first, we discuss an overview of the related work. Next, we describe the digitising and interactive technologies used. This is followed by an explanation of the collection of data, the data analysis, and the results. We then discuss the findings and how digital artefacts can contribute to an engaging and emotional experience even when outside of a museum. Finally, the key points are concluded and further actions are suggested.

2. Related Work

2.1. Online access to digitised museum collections

Many museums have integrated digital technologies into their services for providing access to their collections offsite. Most have an online presence through websites, and some of the more popular museums aim to attract visitors through social media channels. Currently, the Petrie Museum of Egyptian Archaeology and the University of Oregon and the University of California, Davis have websites that allow users to interact with a collection of ethnographic and historical 3D objects on personal computers and mobile devices. In addition, the Petrie Museum of Egyptian Archaeology and The British Museum developed AR apps for use outside of a museum for users to view and interact with 2D and 3D artefacts from their personal mobile devices. These technologies allow users to interact with the 3D artefacts through zooming and rotating. Yet many museums often do not take advantage of the capabilities of these technologies. Frequently, their websites and apps only present images of artefacts that are two-dimensional. It has been shown that some of the key factors of an engaging and successful museum website include virtual 3D tours and interactivity (McIntyre 2007). Therefore, it makes sense that the inclusion of 3D artefacts either on websites or an AR app would enhance the online museum experience. Furthermore, allowing users to view these 3D artefacts from the convenience and familiarity of personal devices can also add to an engaging experience. While 3D artefacts on websites and AR apps are two main methods museum use for sharing their digital artefacts, studies evaluating which method is more engaging and effective for emotional connections are needed.

Digitising artefacts for use on websites and other digital means can increase their availability to a wider audience regardless of time and location. However, it also generates new concerns such as whether this online presence will cause a decrease in physical museum visits (Hume and Mills 2011) and whether the meaning of the physical artefact changes in its digital form since the museum itself forms a part of the object's context (Hogsden and Poulter 2012). While the results of Hume and Mills were inconclusive, Hogsden and Poulter determined that a digital object was just as engaging as a physical object, even though the participants, who were students, never saw the physical object from the British Museum.

Regarding the digitisation of museum objects, past studies considered the methods used for creating 3D models of museum artefacts (Bruno et al. 2010; Hunter and Yu 2010; Fang et al. 2008) and creating interactive content or virtual museums (Wojciechowski 2012; Kim et al. 2011; Petridis et al. 2005). They have also used these 3D models in AR guides and games (Chang et al. 2014; Chatzidimitris et al. 2013; Miyashita et al. 2008) within the museum. Yet few explored the emotional reactions to the digitised objects themselves, particularly when a user's first encounter with an artefact is digital. The E-Curator project (Hess et al. 2011) provided some understanding of this relationship. Specifically, it considered the benefits of the 3D models when used alongside the physical artefact. Objects from the University College London's Museums and Collections were digitised using a 3D colour laser scanning system. In workshops where interactions with the physical artefacts were observed, it was found that users requested to see the details of artefacts, which was later incorporated into the system using the zooming and rotating features. These 3D models were made available on a website and allowed for the examination of artefacts, but further research could be done to evaluate the responses to seeing the 3D models before the physical artefacts.

2.2. Potential benefits for the young and elderly

The North East Museums Hub organised a comprehensive study of United Kingdom museum visitors and reported on data from 2000-2006. They found that 27% of museum visitors are mainly aged 55 and older while those who are 24 and under are the least likely to visit a museum (McIntyre 2007). As museums start to offer more of their collections online, these two groups of visitors may view and interact with digital collections differently.

The younger set, more likely to have grown up with computers and video games (Prensky 2001), 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. Kelly and Groundwater-Smith (2009) found that students wanted a closer examination of artefacts and to make emotional connections with them. Most importantly, students did not want a museum environment with “rows of boring glass cabinets filled with items to be viewed but not touched”. Digital artefacts would enable them to interact with the artefacts in a new environment that they can control from their mobile devices or laptops. As a result, the experience could encourage them to visit museums in order to see the real artefact. This is similar to museum websites that allow users to view and save images of artefacts online, which they can refer to when planning future museum visits (Marty 2011). However, more research needs to be conducted to determine whether 3D artefacts viewed on personal devices can encourage emotional connections.

The older group, who are comparatively unfamiliar with computers or whose computer use is limited (Olson et al. 2011), may not be as adaptable to new technologies. While the elderly are more hesitant to try new technologies when compared to younger people, there was little evidence that they were opposed to using technology in general. They are also 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). Kelly et al. (2002) explored museum accessibility and exhibition methods from the perspective of older visitors, with seating, readability, lighting, noise, and crowds all contributing to their concerns. Online museum collections would enable them to virtually visit a museum from the comfort of their home using technology they are already comfortable with. This can help especially those who are housebound or not well enough to travel. While there are many benefits of 3D artefacts, studies focusing on the elderly and their responses to digitised museum collections are lacking.

2.3. Physical vs. digital museum collections

So far, relatively little has been done concerning the responses of young adults and the elderly to both the digitised museum artefacts and their physical counterparts. However, similar research compared responses to oil paintings and their digital reproductions. In an investigation conducted by Taylor (2001), oil paintings and their reproduction in various forms, including books, computer images, black-and-white glossy photographs, and colour slides, were presented to eighty-six participants for their feedback on their expressional content. Taylor suggested 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 presence influenced participants' responses to the original oil paintings.

Another study by Locher et al. (2001) investigated the responses of seventy-nine participants to nine original oil paintings at the New York Metropolitan Museum of Art and their slide-projected and digital image copies. Of the volunteers, subsets of twenty were created for each format condition in both art-trained and untrained backgrounds. The findings show that the original artwork was rated more interesting and more pleasant than the copies, as well as more surprising, rare, and immediate. These responses were assisted by the influence of the museum environment on artworks. The responses regarding the sameness of the artworks for the trained and untrained were comparable. They also concluded that viewers took into account the limitations of the copies and only focused on the art itself.

Contrasting an original oil painting with one shown digitally on a monitor in a lab, Quiroga, Dudley, and Binnie (2011) observed the eye movements of fourteen participants to determine how the format affected their experience. 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 could be 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 where to view the image.

These studies all focused on using different participants for the digital and physical object conditions. If artefacts are to be made available online, which might lead to a separate museum visit afterwards, further exploration is needed to understand how viewing the 3D artefacts beforehand affects the physical object viewing experience.

2.4. Research questions

Based on our review of past research, we have found that there has been little understanding about the emotional responses of younger and older groups to digitised museum artefacts when first viewed outside of a museum. Additionally, studies exploring how these responses affect the physical artefact experience using the same participants are lacking. As such, our research questions are as follows: 1) Are digital artefacts viewed outside of a museum capable of producing emotional responses in younger and older people?; 2) Are the younger and older people more emotionally connected to 3D artefacts on a website or an AR app?; 3) What are the responses of younger and older people when seeing the physical artefacts after the digital artefacts? Our study aims to answer these questions 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, and evaluating their emotional reactions to these artefacts in each modality.

3. Methodology

3.1. Cultural heritage artefacts

Based on the results from a pilot study conducted at the Powell-Cotton Museum in the UK, which analysed visitors' emotional responses to cultural heritage artefacts (Alelis et al. 2013), the following six artefacts were used in this study: a baboon skull, a bronze bust, a comb, a gourd, a necklace, and a sword. These were the physical objects used to model the digital versions. Since these 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 sword, which was the longest artefact. During the participant sessions, the physical artefacts would be shown along with a short description; these descriptions did not include any dates or ages, only the title of the object, its background, and materials. Most also included its origin country. Figure 1 shows how the physical artefacts were displayed to participants after the digital modalities.

Figure 1. Physical artefacts displayed on a table. Top row: bronze bust, gourd, baboon skull. Middle row: necklace, comb. Bottom row: sword. A short description was placed near the corresponding artefact for the participant to read, along with instructions stating not to touch the artefacts.

3.2. Artefact digitisation process

Autodesk, a suite of 3D design software, was chosen to digitise the museum artefacts. The following Autodesk software was used to create 3D models of all six artefacts: 123D Catch, 3ds Max, and Mudbox. The first application used was 123D Catch. First, a series of photos was taken every few degrees, all 360^{o} around each artefact. Typically, between 25-50 photos were needed for a comprehensive model depending on an object's size and features. These photos were then stitched together using the software in order to create a 3D model; variables such as proper lighting and a diverse background contributed to a more accurate 3D model. 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. The remaining objects, the comb, the necklace, and the sword, were two-dimensional and consisted of basically a front and back. The software was unable to stitch together a suitable 3D model from the pictures after several tries for each of the flatter objects. Therefore, 3ds Max was used to reproduce their 3D models. 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. The files were then imported into Mudbox to smooth out some surfaces and fix any holes.

3.3. Digital artefact modalities

As previously discussed, 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 models 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 younger and older people can access artefacts through these familiar technologies.

Laptops and tablets are becoming ubiquitous learning devices in classrooms (Haglind et al. 2015; Tu and Sujo-Montes 2015) and homebound students are increasingly connecting to the internet using mobile devices and computers (Trentin et al. 2015); these technologies can assist with how students learn about museum artefacts in schools. In addition, many older people already use the internet to seek health-related information (Harrod 2011), and tablets are considered tools to help the elderly or disabled acclimate with technology (Castro et al. 2011). These groups of people who may have difficulty visiting museums can also utilise existing technologies in their homes to learn about museum artefacts. For these reasons, a laptop and a tablet were chosen for this research, in addition to the tablet’s larger screen size compared to a smartphone. The laptop size was chosen for its comparable screen size to the tablet for showing each artefact

3.3.1. 3D models on a laptop

The 3D models were viewed on an Apple MacBook Pro with a 13.3-inch (diagonal) LED-backlit glossy widescreen display. For this modality, the 3D models were first uploaded to Sketchfab.com, a website enabling interaction with user-created 3D models in real-time. A website was then created for the users to interact with the artefacts in a simple, non-distracting environment; their descriptions were listed below each of them. The artefacts were presented on the default white grid background provided by Sketchfab in two rows of three artefacts each (see Figure 2). Due to the size of the laptop screen, only one row of artefacts could fully be seen at a time. After clicking on the button in the centre of an artefact to activate it, users could rotate the objects, zoom in and out, and move the artefacts within its window. However, they were not allowed to view each artefact in its own maximised browser window with the purpose of keeping the museum context of displaying multiple artefacts within a concentrated space.

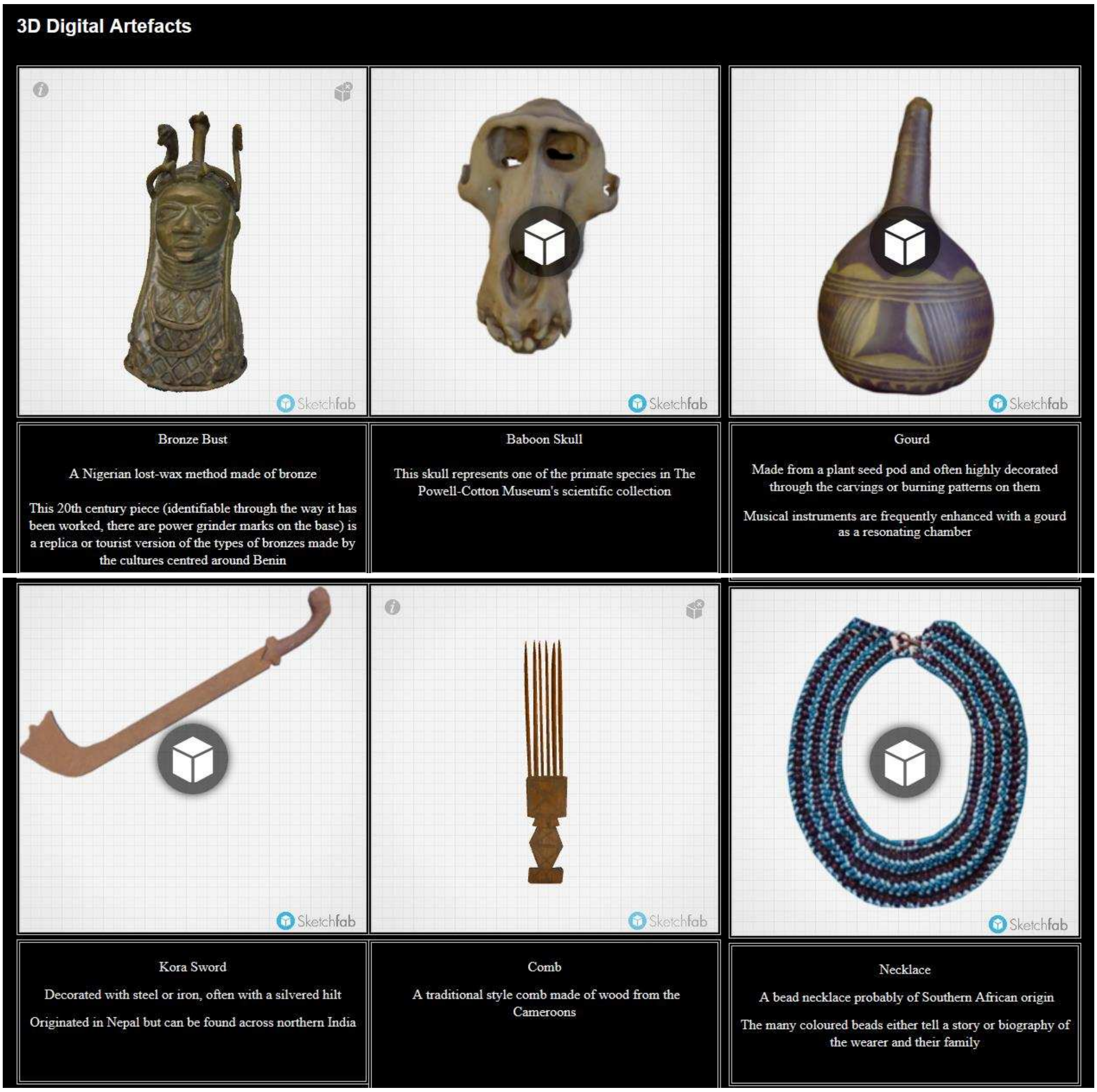

Figure 2. Webpage of 3D artefacts presented on the laptop. Top**:** bronze bust (activated), baboon skull, gourd. Bottom: sword, comb (activated), necklace.

3.3.2. Augmented reality on a tablet

For the AR modality, the 3D models were viewed on a 7-inch Samsung Galaxy Tab with a WSVGA (1024 x 600) Display Resolution. This modality used the same files as the 3D models. The software Unity was used to create the AR interface. Lighting was added using two Directional Lights, one to illuminate the front and another for the back. In order to display the AR artefact, the software required an image target. Each image target had a different, non-repeating pattern on one side that was randomly matched with one 3D model. The artefacts were scaled down to fit in the centre of their corresponding image targets. The image targets were printed out and attached to a 2-inch by 3-inch piece of cardboard. The same, short description of each artefact could be found printed on the other side of the image targets. During the participant sessions, all six image targets were lined up randomly on the table and participants were told they could choose them in any order. Using the tablet, users could manually rotate the artefact using the image target, they could manually zoom in and out, and they could move the artefacts anywhere they wanted to on the table using the image targets (see Figure 3). While the tablet was capable of recognising more than one image target at a time, few participants realised 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.

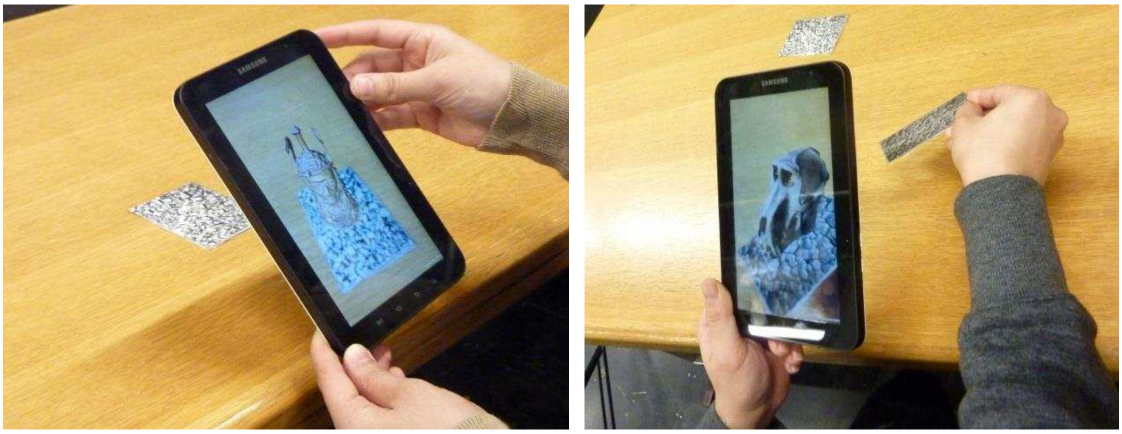

Figure 3. Some of the AR artefacts seen through the tablet: left: bronze bust; right: baboon skull.

3.4. Participants

A total of forty volunteers participated in the study, of which twenty were older people aged 65 and over (71.3 ± 4.612), and twenty were younger people aged 18-21 (19.4 ± 0.995). The first forty eligible people who responded to emailed advertisements and whose schedules coincided with available session times were selected to participate.

The ages for the elderly were based on the default retirement age of 65, a stage in life when they have more free time. Choosing to focus on this age group would provide an understanding of how they feel about innovative technologies and museum objects. Young adults typically attend university or seek employment at the age of 18, allowing them the freedom to choose how to spend their money and free time. In addition, students usually graduate university and are considered adults at the age of 21. Therefore, this formative age group could provide insightful feedback on how engaging the technologies are and their thoughts on various representations of digital museum artefacts.

3.5. Study procedure

This was a within-subject study using counter-balancing in order to minimise order effects for the two digital modalities. In total, there were three artefact modalities to each participant session, all consisting of the same six objects: 1) Viewing and interacting with either the six artefacts presented in 3D on a laptop or AR on a tablet first; 2) Viewing and interacting with the six artefacts presented in either the 3D on a laptop or AR modality second depending on what was shown first; and 3) Viewing, without touching, all six physical artefacts, which is usually how visitors would interact with an artefact in real-life while at a museum. In order to represent the experience of viewing online museum collections before viewing the physical artefact, the digital artefacts were shown first and the modality with the physical artefacts was always shown last. 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 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 so participants can evaluate them under consistent conditions. In addition, since past studies have indicated that the museum environment influences emotions (Locher et al. 2001; Taylor 2001), showing all the modalities, including the physical modality, outside of the museum can further demonstrate the potential for the artefacts to influence emotional connections.

All sessions were one-on-one and held on campus at the University of Kent. Each participant was seated behind a desk in front of either the laptop or tablet, depending on the modality. A video camera was set-up behind the desk and facing the participants to record not only their thoughts, 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. The activity on the laptop screen was also recorded using QuickTime software. This was necessary for measuring how much time participants spent with each artefacts, 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 verbalising their thoughts about it. For the first artefact modality, half of the participants were given the 3D models on a laptop and half were given the AR format on a tablet. They 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. Utilising the think-aloud method (Charters 2003), participants were then 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. 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?"

After participants finished interacting with the artefacts in a modality, they were given a questionnaire asking them to rate how enjoyable the experience was based on a scale from 1 to 10, with 10 being the highest enjoyment. Additionally, if they 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. The emotions consisted of the six basic emotions taken from Ekman's research on facial expressions of emotions: anger, disgust, fear, happy, sad, and surprise (Ekman 1971), along with options for indifference and other. These emotions were chosen because Ekman found that these were universal and easily identifiable regardless of culture. The six emotions are also distinct and do not overlap with one another. Participants were also asked to state the artefact they liked the most and the least along with their reasons why.

For the second artefact modality, participants were shown the six artefacts in the digital modality they did not previously see, either the 3D models on a laptop or in the AR on a tablet. They were again given instructions on how to interact with the artefacts and asked to verbalise and explain what they were thinking and doing. A questionnaire with the same information as the previous one was given to them once they finished interacting with the artefacts.

For the third 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 real versions later on during the session. Participants were not allowed to touch any of the artefacts to simulate the experience of viewing artefacts in a museum. However, they could look at any of them as closely as they liked. Again, the same questionnaire was given to them once they finished viewing the artefacts.

Following the artefact modalities, participants were asked to complete an Emotional Intelligence Questionnaire developed by Schutte et al. (1998). This was 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”. This would help clarify if participants’ emotional intelligence influenced their responses during the study.

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

3.6. Data analysis

The results were analysed using IBM SPSS Statistics Version 19 to explore the effects of artefact modality on older and younger participants. All sessions were transcribed and the amount of time each participant spent with each artefact in each modality was timed. Only the actual amount of time spent with the artefact was included; if a participant took time to become familiar with the technology, that time was not counted. Participants were asked to verbalise what artefact they were looking at and when they were finished. Since participants were facing away from the video camera and the artefacts they were looking at cannot be seen, the official start time was based on the method of Tillon et al. (2011), who measured the time participants spent on both an AR guide and artworks starting from when they stopped in front of the artwork. The participants in this study were sitting for all three modalities to maintain consistency with the 3D models on a laptop modality, since people do not usually move when using a laptop. Therefore, the start time for each artefact was when participants started talking about the 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 data first had to be processed before any analysis could be done. Older people typically spent longer than the younger people with interactions, 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. By converting the times spent with each of the three modalities into a proportion of their total interaction time, all participants' data could be compared uniformly. After the conversion, the values for how long each participant spent with each modality were between 0 and 1.

Answers to the questions concerning their emotional responses to the artefacts were converted to a quantifiable measure. First, the number of basic emotions were counted and given a total number within each modality. In addition, interest was frequently mentioned by the participants and thus counted. As a result, 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 needed a value for their valence and arousal, concepts that were applied to emotions in a circular spatial model by Russell (1980). The valence defined how pleasant or unpleasant an emotion was. The 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 et al. 2013). This approach was chosen due to its inclusion of Ekman's six basic emotions as well as "interest" and "no emotion", the latter of which will be referred to as "indifference" to maintain consistency with the emotions listed in the questionnaires. It also organises emotions based on Plutchik's circumplex model (Plutchik 1982), which expands on

Russell's model by organising emotions similar to a colour wheel, with opposite emotions located across from each other and similar 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 score, and S_2 score, which was the arousal score (see Table 1).

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. The ranking and emotion data were ordinal values that appeared multiple times. Therefore, these data were analysed using non-parametric tests.

Table 1. CAAT Scoring System

Emotion	S_1	S_2
Anger	3.3	6
Disgust	2.3	5
Fear	2	6
Joy*	6	6
Sadness	2	2
Surprise	3.3	6
Interest	4.7	5
Indifference	0	0

* Happiness

4. Findings

4.1. 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 twelve months as well as frequency of viewing museums' collections online in the past twelve months. Table 2 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.

Table 2. Participant Technology and Museum Background

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

* M = mean; SD = standard deviation

All younger participants had experience with mobile devices compared to about half of the older participants. The Independent T-Test showed that younger participants (1 ± 0) had significantly different mobile device experience compared to the elderly (0.55 ± 0.510), $t(38) = 3.943$, $p < 0.001$, $r = 0.54$, 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 (2.15 ± 1.599) and younger participants (2.55 ± 1.191) had no significant difference in their familiarity with 3D models, $t(38) = 0.897$, $p = 0.375$, $r = 0.14$. However, the younger group (1.55 ± 1.504) had a significantly higher familiarity with AR than the older group (0.65 ± 1.089), $t(38) = 2.168$, $p < 0.05$, $r = 0.33$.

Between the twenty older and twenty 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 (4.15 ± 1.387) visited museums a statistically significantly higher number of times than the younger group (1.90 ± 1.210), $t(38) = -5.468$, $p < 0.001$, $r = 0.66$. 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 (1.20 ± 1.609) and younger participants (1.45 ± 1.504), $t(38) = 0.508$, $p = 0.615$, $r = 0.08$.

4.2. Time spent with artefacts

In order to understand how engaged the participants were, we analysed the time spent in each modality. 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 (Yalowitz and Bronnenkant 2009; Melton 1988). Studies have shown that time spent with artworks or exhibits can be a measure of how engaging they are to visitors as well as indicate that visitors are learning (Serrell 1997).

As a whole, all forty participants spent the most time with the AR on a tablet modality with a mean proportion 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 the artefact. Mauchly's Test of Sphericity indicated that the assumption of sphericity had been violated ($\chi2(2) = 11.31$, $p < 0.05$); therefore, a Greenhouse-Geisser correction was used to correct the degrees of freedom.

Post-hoc tests using the Bonferroni correction show 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 the 3D artefacts than viewing the physical artefacts (0.417 ± 0.099 vs. 0.146 ± 0.061), also statistically significant ($p < 0.0005$). This determined that the change from a digital modality to the physical artefacts modality caused a statistically significant decrease in the time spent with the artefacts ($F(1.590, 62.028) = 94.604$, $p = < 0.0005$). 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.

The results from an Independent T-Test (see Table 3) showed that there was no significant difference between older and younger participants 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 ($t(38) = 0.359$, $p = 0.721$, $r = 0.058$).

Table 3. Differences in Age for Time Spent and Ranking in each Artefact Modality

		Younger (18-21)		Older (65+)	
		M	**SD**	**M**	**SD**
Time Spent with Artefacts (proportion of time spent)	**AR**	0.431	0.072	0.441	0.115
	3D	0.420	0.084	0.413	0.113
	PA	0.149	0.044	0.142	0.075
		Mdn	**IQR**	**Mdn**	**IQR**
Ranking of Enjoyment (on a scale from 1= Low to 10 = High)	**AR**	8	8-9	8	7.25-10
	3D	8	7.25-10	8	7.25-10
	PA	8	7-9	10	9-10

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

4.3. Ranking of artefacts

As mentioned previously, measuring time spent within a museum can indicate how engaging its collections and exhibitions are (Serrell 1997). Therefore, in addition to measuring the time spent we also analysed the enjoyment of each modality. After each of the three modalities, participants ranked their enjoyment of the artefacts on a scale of 1 to 10, with 10 being the highest enjoyment.

Among all participants, the physical artefacts modality was enjoyed the most with a median of 9.00 ± 3.00 Second was the AR on a tablet modality with a median of 8.00 ± 1.00 and third was the modality with the 3D models on a laptop with a median of 8.00 ± 3.00. A 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, $\chi2(2) = 20.217$, $p < 0.001$.

Observing the differences between the young and elderly, the older participants ranked all the modalities higher than the younger group (see Table 3). 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 ($U = 143.00$ $p = 0.121$, $r = -0.25$).

4.4. Emotional responses

In order to understand if digital artefacts and physical artefacts removed from a museum can encourage emotional connections, we analysed different variables of emotional responses. Previous studies have claimed that emotional responses to artworks and objects in museums are influenced by a museum's environment and seeing original objects (Gadsby 2011; Locher et al. 2001; Taylor 2001). In addition, these emotional responses are considered the most important part of understanding museum objects (Taylor 2009). This, it becomes important to identify if digital artefacts and physical artefacts removed from a museum can similarly generate emotions.

4.4.1. Emotion count

After each modality, participants listed the emotions they felt on questionnaires. We focused on the six basic emotions, plus interest. Each modality had six artefacts;

therefore if a participant felt happiness in response to seeing each artefact, the total emotion count was six. Our aim was for each artefact 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. Our 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 ± 4.00. Second was the physical artefacts modality with a median of 3.00 ± 3.00. Third was the modality with the 3D models on a laptop with a median of 3.00 ± 2.00. A 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, $\chi^2(2) = 4.436$, $p = 0.111$.

Observing the differences between the young and elderly (see Table 4), 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.

Table 4. Differences in Age for Emotion Data in each Artefact Modality

		Younger (18-21)		Older (65+)	
		Mdn	**IQR**	**Mdn**	**IQR**
Emotion Count	**AR**	3.5	2.25-5.75	5	3.25-6
	3D	3	1.25-3.75	4	3-5.75
	PA	3.5	2-5.75	4	1-6
S_1 (on a scale from 1= Unpleasant to 7 = Pleasant)	**AR**	3.77	3.32-4.65	4.1	2.98-4.69
	3D	3.77	3.3-4.43	4.44	2.99-4.65
	PA	3.31	3.15-4.33	3.55	3.3-4.33
S_2 (on a scale from 1= Low arousal to = High arousal)	**AR**	6	5.34-6	5.84	5.25-6
	3D	5.75	5-6	5.5	4-6
	PA	6	5.17-6	4.84	4.34-6

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

4.4.2. 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 and surprise), and two had scores over 4 (joy, interest). All seven emotions had an arousal score of at least 4, except for surprise, with a score of 2. 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 ±1.32 and the median value S_2 score was 6.00 ± 0.66. Second was the median value S_1 score for the 3D models on a laptop modality at 3.99 ± 1.37 while the S_2 score was second highest for the physical artefact modality with a median value of 5.88 ± 1.00. Third was the S_1 score for the physical artefact modality with a median value of 3.65 ± 1.10 while the third S_2 score was for the 3D models on a laptop modality with a median value of 5.42 ± 1.00. 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. A 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, $\chi^2(2) = 4.353$, $p = 0.114$.

With respect to age differences and S_1 score (see Table 4), the results of the Mann-Whitney Test showed that the younger and older 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 caused participants to feel emotions with about the same valence regardless of age.

For the S_2 scores (see Table 4), the results of the Mann-Whitney Test showed that the younger and older 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 caused participants to feel emotions with about the same intensities regardless of age

4.4.3. Emotional Intelligence score

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, $t(38) = -0.654$, $p = 0.517$, $r = 0.11$.

5. Discussion

The main purpose of this study was to explore whether younger and older people engaged with and emotionally responded to cultural heritage artefacts outside of a museum, first in two digital modalities, 3D models on a website which were shown on a laptop and an AR app on a tablet, and then lastly in the physical modality. In particular, we were interested in the modality's influence on three variables: length of time spent with the artefacts, ranking of enjoyment, and emotional responses.

5.1. Digital artefacts are capable of producing emotional responses in younger and older people

Our findings show that digitised artefacts viewed outside of a museum on two different devices can generate emotional responses in both younger and older people. This contrasts with past research that indicated participants' responses were influenced by the museum environment in which the original oil painting was displayed (Quiroga et al. 2011; Locher et al. 2001; Taylor 2001). Despite the absence of the physical presence of a museum, the modalities enabled participants to feel emotions while viewing and interacting with 3D artefacts.

5.2. Despite age differences, there was no difference between digital modalities in emotional connections to artefacts

Age was not an influential factor in experiencing emotional responses to either the 3D models on a laptop modality or the AR on a tablet modality shown outside of a museum. Past studies have shown differences between older and younger people and their technology backgrounds and skills (Olson et al. 2011; Broady et al. 2010) and our participants had a significantly different number of museum visits (see Table 2); therefore it was surprising that for many of the variables, our findings showed no significant differences between these two age groups across the digital modalities.

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 one modality was not better than the others in terms of facilitating 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 computer skills do not influence enjoyment in virtual museums (Sylaiou et al. 2010).

Furthermore, these two groups have similar motivations for visiting physical museums. The elderly are seeking new experiences, entertainment, and learning opportunities (Kelly et al. 2002). They also welcome opportunities to reminiscence (Aldridge and Dutton 2009). Younger people want engaging experiences, innovative services, individualised learning, and emotional connections (Gofman et al. 2011; Kelly and Groundwater-Smith 2009; Griffin 2004). 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 (2012). Lastly, the number of emotions felt and their S_1 and S_2 scores indicate they both made a similar number of emotional connections in each digital modality.

5.3. Younger and older participants still respond emotionally to physical artefacts even after viewing the digital 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 elderly’s enjoyment significantly increased in the physical artefacts modality. This could be supported by their significantly higher museum visits than the younger participants (see Table 2) and past research that found that museum visitors are mainly older people (McIntyre 2007). However, this differs from the results of the art-trained and untrained comparison study (Locher et al. 2001), which found that the original artworks seen in the museum were generally rated more interesting and pleasant regardless of an art background. 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.

Due to the different conditions for the originals and copies, our findings conflict with the results of Locher et al. (2001), which showed that the reproductions generated different responses to the physical oil paintings. While they did not specifically investigate emotional responses, they did rate how surprising, interesting, and pleasant the artworks were, and these ratings were the only values that significantly differed between the copies and original paintings. In our results, the similar valence and arousal scores for each modality show that participants did not have significantly different emotional responses to the digital and physical artefacts.

Taylor (2001) claimed that the original artworks and their coloured, slide reproductions 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 slightly differs from ours, our results are comparable. Similar to our research, he found no significant difference in the number of emotions identified in the originals and any of the copies. In addition, his 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.

Quiroga et al. (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. The interactive element of our digital modalities explains why our 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 suggest that the digital modalities allowed for more interaction, thus extending the amount of time with the artefacts.

However, both digital modalities still produced a similar number of emotions as the physical artefacts despite participants spending more time with them.

Our findings show that regardless of computer skills and age, the combination of digital modalities with museum artefacts facilitate engaging and emotional experiences outside of a museum.

5.4. Summary of contributions

Our study contributes to current knowledge about museums, their digital implementations, and HCI by providing an understanding that online digital cultural heritage artefacts viewed on personal devices can enable emotional connections, even though the artefacts are digitised and viewed outside of the museum. Additionally, older and younger people can be engaged with and emotional connected to 3D artefacts whether they view them as AR on a mobile device or on a website using a laptop.

As museums create 3D models of their artefacts and make them available online, this insight can also highlight the value of digital artefacts since they can provide an emotional experience similar to the physical artefacts.

5.5. Limitations

There were some limitations of our research design, the first being that each participant was shown all six artefacts in each modality. This may have caused the novelty of the artefacts to lose some of its impact and the participants to spend less time viewing the physical artefact, the last modality shown. This method is similar to the study by Taylor (2001), which showed the same participants the same twenty works of art, but they were shown each artwork only once in one of five different formats: the original oil painting in a museum, digital images, black and white photographs, colour slides, and printed pages from a book. Our study also differs from Locher et al.'s (2001) study where some participants were shown the original oil paintings in a museum, others were shown the paintings in the slide condition in a laboratory setting, and another group were shown the computer condition in a laboratory setting. However, both these studies focused on the effect of different presentation conditions on non-art-trained users and both found that the museum setting influenced their responses.

All participants were shown every artefact in each modality in order to understand the affects the digital modalities may have on viewing the physical artefacts. Ultimately, both digital modalities were necessary since the 3D artefacts on the website allowed the examination of all angles of the artefact, including the bottom, whereas the AR method did not. The AR artefacts enabled participants to move the image targets to any location on the table, and if used in real life, they could move it anywhere both indoors and outdoors. Together, these offer greater detail of artefacts through their zooming and rotating capabilities and provide an example of how the digital modalities can enhance the artefact experience outside a museum.

In addition to all participants seeing every artefact in each modality, another potential limitation involves the technology participants used in our research. There is the concern that the digital modalities could have contributed to participants' emotional responses. Similar to how an artefact's presentation in a museum environment can influence emotional responses (Gadsby 2011; Locher et al. 2001; Taylor 2001), the digital modality can also be influential. While the questionnaires after each modality specifically asked "which artefact made you feel the following emotions", the modality could have affected their emotional response, especially if the technology was new to a participant.

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 2), many participants, regardless of age, still took some time to get used to holding the tablet with one hand and hovering it over the image target in the correct angle for the AR artefact to appear, while at the same time moving the image target with the other hand to see the different perspectives.

Regarding the laptop, it also required a few tries before participants recalled which mouse buttons can rotate, zoom in and out of, and move an artefact. However, once the artefact was positioned on the computer screen, no other mouse movement was required to enjoy and inspect the artefact, unlike with the AR method, which forced the user to continually hold up the tablet with one hand. Also, participants quickly learned that by holding the tablet too close to the image target, they would not get a full view of the artefact. This, along with the tablet screen size, prevented them from immediately recognising an object, something that might not occur in real life when the whole object is readily visible. While these frustrations 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. Nevertheless, our findings show that any struggles with adapting to the technology did not affect the enjoyment and emotions felt towards the artefacts.

6. Conclusion and Future Work

The comparison of younger and older people in the context of digitised artefacts is one that has been lacking in cultural heritage artefact studies. In addition, studies examining the same participants' responses to seeing the digital artefacts before the physical artefacts were underrepresented, and therefore is an important contribution to these research areas. The responses from participants and the results from quantitative tests show that the digital modalities were successful in creating an enjoyable, emotional experience. As a result of these findings, museums could consider presenting 3D models of their artefacts on their websites and also make them available as a downloadable AR app for tablets and other mobile devices. This would enable users to view them on the go or even supplement their museum visit using their own mobile device. For older audiences who are unable to travel, accessing 3D models on museum websites would allow them to simultaneously enjoy museum artefacts and become more comfortable with computers and the types of technology they offer.

Further research could be carried out to see how visitors emotionally respond to physical artefacts exhibited in a museum after first seeing the 3D artefacts on their personal devices. Afterwards, it could also be useful to see if interacting with the 3D alongside the physical artefacts enhances the overall museum visit.

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Figure Captions

Figure 1. Physical artefacts displayed on a table. Top row: bronze bust, gourd, baboon skull. Middle row: necklace, comb. Bottom row: sword. A short description was placed near the corresponding artefact for the participant to read, along with instructions stating not to touch the artefacts.

Figure 2. Webpage of 3D artefacts presented on the laptop. Top: bronze bust (activated), baboon skull, gourd. Bottom: sword, comb (activated), necklace.

Figure 3. Some of the AR artefacts seen through the tablet: left: bronze bust; right: skull.