Viking VR: Designing a Virtual Reality Experience for a Museum

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ABSTRACT

Viking VR is a Virtual Reality exhibit through which viewers can experience the sights and sounds of a 9th Century Viking encampment. Created as part of a major museum exhibition, the experience was developed by an interdisciplinary team consisting of artists, archaeologists, curators and researchers. In this paper, approaches to the design of authentic, informative and compelling VR experiences for Cultural Heritage contexts are discussed. We also explore issues surrounding interaction design for the long-term deployment of VR experiences in museums and discuss the challenges of VR authoring workflows for interdisciplinary teams.

Author Keywords

Cultural Heritage; archaeology; virtual reality; museums; digital art

ACM Classification Keywords

H.5.m [Information interfaces and presentation (e.g., HCI)]: Miscellaneous;

INTRODUCTION

Designing museum exhibitions is increasingly seen as a storytelling discipline in which artefacts are used to illustrate past events, adding tangible flesh to historical bones [3]. Rather than the intrinsic properties of objects, it is their context that is all-important; in particular what objects can tell us about human experience in times past. The latest generation of Virtual Reality (VR) technologies offers compelling ways to enable museum visitors to experience places or objects which cannot be exhibited, reconstructed or re-enacted physically due to budgetary constraints, limited space or staffing. Museums are beginning to experiment with this technology, often as a corollary to existing exhibitions [5]. However, a number of substantial challenges face institutions or practitioners developing VR experiences for museums and galleries.

Consumer VR systems are for the most part fragile and unwieldy and often rely on delicate cabling and connections, unsuited to constant use in busy public venues. Moreover designing VR experiences involves overcoming a number of problems, including simulation sickness, accessibility and safety [12], all of which have yet to be solved definitively.

Just as practitioners in the entertainment industries are developing ways of translating and reconfiguring conventions and workflows from games, television and cinema into this medium [25], the same process is taking place in the developing field of VR for Cultural Heritage [7].

Figure 1: A still from the VR experience *Viking VR*

Viking VR is a Virtual Reality Exhibit presented as part of *Viking*; a touring exhibition developed by the British Museum in conjunction with 4 other major UK museums, exploring how the Vikings transformed life in Britain. *Viking VR* was designed to be installed in its own space within the exhibition at the Yorkshire Museum. The experience consists of 3 custom-built Head Mounted

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Displays (HMDs), each showing one of 4 vignettes; animated 3D computer graphic (CG) scenes that surround the viewer, placing them at one of four different locations within a Viking encampment (see figure 1). Each vignette was built around individual artefacts found at a specific archaeological site, forming a clearly legible narrative link between the museum exhibition and its medieval subject matter.

A multidisciplinary team including curatorial and technical staff from the host museum, a 3D artist, sound designers and archaeologists from the University of York collaborated on the design and development of the VR experience over a period of 8 months leading up to the exhibition. Our goal was to explore how VR might be integrated into curatorial practice, adding to the storytelling tools at the curator's disposal. As this was the first time that the team had collaborated and also the first time that any of the team had created a public-facing VR piece, we reasoned that the project might well generate useful information for practitioners considering venturing into this space. Crucially this exploratory piece could not be a prototype but needed to be fully functional; a robust and low-cost system that could be used by visitors within a popular visitor attraction for long periods of time with minimal technical support.

In this paper we reflect on the experience of designing and deploying *Viking VR* and explore a number of challenges we encountered. We describe our design rationale and possible approaches to creating compelling, informative VR experiences from archaeological evidence. We also discuss obstacles to communicating design decisions in a new medium, practical constraints around the deployment of VR technology in museum contexts and considerations of authenticity and curatorial storytelling.

BACKGROUND

Reconstructing the Past

Using reconstructed scenes to help the public engage with the past is a practice that predates digital technology. Painted panoramas and dioramas: miniature models of historical scenes complete with moving elements, light and sound became popular in the 19th Century both as entertainment and as an educational resource [19][22]. Later, naturalist Carl Akeley pioneered habitat dioramas through which visitors could experience a sense of immersion in natural environments through combinations of taxidermy, painting and sculpture [2]. Immersive storytelling has become integral to contemporary approaches to the representation of Cultural Heritage. Accurate reconstructions of heritage sites such as Lascaux [9] and 'living museums' such as Skansen in Stockholm or the Weald and Downland Museum in Sussex often serve a dual function: enabling visitors to learn about the past while also serving as a testbed for current archaeological thinking [15].

More recently, digital imaging technology has become a frequently used tool for representing the past and CG reconstructions of historical sites have become a staple of television documentaries [16]. Archaeology has a disciplinary tradition of exploiting the narrative affordances of digital media. 3D computer graphics has had an established role within archaeological practice since the 1980s and continues to be the subject of critical discourse and innovation in archaeology[3].

Film, television and games are increasingly seen as a space for archaeologists and historians to explore, discuss and test models and theories and to engage with members of the public. For example, the popular *History Respawned* YouTube channel [17] hosts historical discussions around play-throughs of video games set in historical periods. History Channel's *Vikings* series [18] led to an offshoot documentary project *Real Vikings* [11] in which the programme's locations, sets and props were used to explore and discuss Viking history. Virtual digital environments such as Second Life have also been used as sites for archaeological experimentation [21].

Digital reconstruction of historical events is not an uncontroversial practice. Archaeologists and historians are necessarily cautious about reconstructing complete environments in detail as this process often involves extrapolating or interpreting from partial historical sources [5]. Although individual artefacts can be rebuilt with a degree of confidence, their surroundings must often be inferred from their context (weapons might imply the presence of warriors), from general deductions (charcoal implies settlement as nearly all cultures use fire) or from evidence from other sites (a ship might be reconstructed from a few timbers based on more complete finds from elsewhere).

The risk in creating compelling reconstructions based on partial historical records is that members of the public are unable to distinguish between authentically reconstructed elements of a scene or story and dramatic devices or interpretations [3]. This can be particularly problematic with fictionalized representations of historical events where the alteration of characters, events or settings for narrative and dramatic effect can be genuinely misleading. For example: the film *Braveheart* [13] has been criticized for its inaccuracy and consequent effect on the popular understanding of Scottish history [10].

Beale [3] suggests that preserving discussion and decision-making processes and making them available alongside visual reconstructions is one way of clarifying this process. This approach has also been taken in some television documentaries: BBC series *Planet Dinosaur* used detailed discussions of the fossil evidence behind each of their reconstructed creatures to highlight strengths and weaknesses of the reconstruction process [24].

Virtual reality for Cultural Heritage

Recently, a renewed interest in Virtual Reality has led to increasing experimentation with immersive digital environments and the launch of a number of platforms for VR creation and consumption. These are beginning to be used by historians, archaeologists and curators, often in order to provide a deeper sense of immersion in historical reconstructions [7].

Virtual Reality is often used as a catchall term for two very different approaches to imaging [25]. The first, described here as Cinematic VR (CVR) refers to 360-degree video captured by a camera or series of cameras. This approach means that live subjects and environments can be captured, however, interactivity is difficult to achieve: most experiments in interactive CVR have so far been limited to simple branching-narrative approaches. Projects such as The British Museum's work with Oculus [6] exemplify this approach: often using a 3D GUI familiar to web users to help viewers navigate between non-interactive filmed scenes.

The second common approach to VR, referred to here as 3DVR, uses real-time 3D computer graphics to create fully interactive experiences: viewers can potentially move around scenes, interact with objects and explore at their own pace. This approach is being used increasingly in Cultural Heritage settings. ChroniclesVR's work for the Waterford Viking Triangle [8], the Virtual Dutch Men's *EUseum* [26] project and The Smithsonian's work in conjunction with Intel [27] all use powerful computers and high-resolution HMDs to either reconstruct scenes from the past or to enable viewers to access reconstructed galleries remotely and at their own pace.

VR is also currently dominated by 2 distinct types of technical platform [25]. The first is to use powerful computers with separate HMDs, sensors and controllers. This approach, exemplified by systems such as the Oculus Rift and HTC Vive allows for high-quality graphics and sound but requires a fairly complex technical setup: the Oculus Rift with Touch for example requires no less than six separate wired and wireless connections to function [23]. The second approach is to use the affordances of high-end mobile phones (accurate sensors, high resolution screens etc.) placed within a headset consisting of little more than a casing and a pair of plastic lenses. This approach has the advantage of needing no external connections but means limited graphical fidelity can be achieved [25].

Although impressive in terms of both technical achievement and visitor impact, projects such as those cited above exemplify challenges common to the design of VR museum exhibits. All rely on delicate consumer-grade technology and require full-time supervision by trained members of staff both to protect the equipment from harm and to assist visitors in putting on the HMD and controllers.

DESIGNING FOR CULTURAL HERITAGE

In the remainder of this paper, we explore the specific challenges encountered in the design, development and deployment of *Viking VR*. Our aim in designing a VR experience to form part of *Viking* was quite specific. We hoped to help visitors better understand and engage with a particular historical event: the winter camp of the Viking 'Great Army' in Torksey, Lincolnshire, UK in CE 872-3. Torksey is unusual as an archaeological site as its finds represent a single massive event. Torksey is also notable for its scale as several thousand warriors, camp followers, traders and artisans lived there for less than a year making the camp one of the largest settlements in England at the time [14]. The extent of the camp highlights the size of Viking armies in the late ninth century and finds from the site demonstrate a number of significant features of Viking culture, such the scale of looting of gold and silver, as well as the extent of international trade (e.g. through Arabic coins found at the site).

However, Torksey also presents a particularly challenging set of common archaeological and curatorial problems. The site of the camp is now open farmland and details of its composition are only known through a number of objects recovered by amateur metal detectorists and by archaeologists [14]. Objects found at the site are, in many cases, heavily weathered and damaged, some consisting only of partial fragments (see figure 2). To the archaeological community, these objects are significant in terms of the detailed information they give about life in the early medieval period; however, many would be unfamiliar to most museum visitors.

We felt that VR could be a particularly appropriate way of placing these objects in a context that would unlock the human stories around them, enabling visitors not only to understand what took place at Torksey but also to be able to draw parallels with modern culture. We also predicted that VR could accomplish this in a way that would allow a high level of corollary detail to be included, detail that might be hard to understand if other techniques were used. For example, background information about climate and environment would add little to a written description of the site. However, a VR experience that captured the harshness of the climate might encourage the visitor to reflect on its effect on the culture and lifestyle of the period.

Figure 2: Example of an object (a gaming piece) found at Torksey

Ways of Working

Working with VR presents a number of challenges both to museum staff developing content in-house and to designers making work for Cultural Heritage venues. Creating digital content for museum exhibitions is a well-developed field. Many museums routinely contract digital agencies or individual artists to develop interactive displays, projections or films, while some larger institutions have the capacity to develop such content in-house. Workflows have become well established and due to the ubiquity of network technology and high-resolution screens, it is relatively easy for experts within an institution to work with artists and designers to develop visual content collaboratively even at distance.

With VR, this practice becomes more difficult as few institutions currently have daily access to headsets and powerful computers with which to feed back on and discuss content during development. It was important therefore to establish a way of working that enabled the museum, archaeologists and artists to communicate effectively during the project. This was particularly important given the relatively short timelines involved.

VR within the Exhibition

Besides the curatorial intent behind the experience, it was important to consider how the VR exhibit would relate to the rest of the exhibition in spatial terms. The content of the exhibition was largely a fixed point: established well in advance by curators at the British Museum, the Yorkshire Museum and other participating venues. The VR exhibit had to complement and extend the show, adding detail to an existing story.

We had to consider, how would visitors transition from the relatively familiar spaces of the museum with their cases of objects and interpretation panels to the virtual spaces we were planning to develop? Given that consumer VR technology is relatively new we could assume that many visitors would not have encountered VR before. How could they be prepared for engaging with our digital spaces, using an unfamiliar technology? How could they quickly orient themselves in these virtual spaces and start to engage with the content therein? The visitor experience needed to be accessible, enjoyable and above all social: encouraging visitors to discuss, share and explore. The stereotypical VR experience, with a solo user insulated from the outside world was not appropriate here.

Practical Considerations

In practical terms too, the VR installation would have to work alongside other exhibits. Although a small room had been allocated to hosting the VR experience, this was open to the rest of the exhibition. Sound 'spill' from audio sources into and out of the VR space was a serious concern. Visitor numbers also had to be considered. As a heavily marketed exhibition in a popular public venue, the VR experience would have to accommodate thousands of visitors per week. Flow into and out of the space would have to be carefully planned and the experience needed to be relatively short, as queues were likely to form.

Lastly and in contrast to the majority of the exhibitions described in the background section of this paper, the VR experience would have to work completely reliably for the entire six-month period of the exhibition with minimal support from staff. A single gallery assistant, who would not necessarily have any technical training, would typically staff the exhibition, which extended over an entire floor of the museum.

Security, Health and Safety

A substantial obstacle was robustness and reliability. Expensive consumer headsets, cabling or sensors would be vulnerable to accidental damage, vandalism or theft. Health and safety was a further concern. The foam and fabric padding used around the eyepieces and strapping of consumer VR HMDs is difficult to sanitise and given the large numbers of visitors expected to attend the VR experience, it was essential that the museum be able to sanitise any hardware handled by visitors. The main feature of VR - replacing the user's view on the world with a different one - also raised safety issues. We would have to minimize the risks of visitors colliding with each other or with other objects in the museum while experiencing the exhibit.

Platform and Type of VR vs Complexity and Realism

As discussed, two main types of technical platform currently exist for VR: tethered systems using a powerful computer and separate sensors and HMD and less expensive, less powerful but self-contained systems using a mobile phone as computer display and sensor. In deciding which of these approaches to adopt for *Viking VR*, a number of factors were considered. The first was cost per unit: as the project had a fixed equipment budget, less expensive solutions would mean more HMDs to use in the exhibition. At the time of planning, a powerful computer and separate HMD could cost up to 5 times the price of a mobile phone based system.

The decision also had to be made whether to conceive of the experience as a piece of CVR: involving live action or high-resolution CG video or to use real time 3D. In making this decision, a number of factors also needed to be considered. Budget was once again a factor and the planned subject matter would necessitate a high degree of craft skill and resource either way. A live-action filmed reconstruction was out of the question due to the subject matter: we certainly did not have the budget to build a convincing replica environment. CG or mixed-reality reconstruction was a more reasonable approach and, as one of the team members was an experienced 3D artist, CVR or 3DVR approaches were both possible.

The chief advantage of a CVR version would be a higher degree of photorealism and the ability to include more complex scenes, more characters and more elaborate visual effects. On the other hand, a 3DVR approach would have the advantage of a visually sharper output as 3DVR is adaptive in terms of its field of view (unlike CVR, the entire 360-degree view does not have to be stored and rendered every frame). 3DVR also has the advantage of a more flexible workflow as the rendering and postproduction phases needed for CVR are not necessary, allowing for the easy addition of new content throughout a project, rather than having to commit to specific details at a very early stage. This was particularly important given the experimental nature of the piece and the unusual interdisciplinary nature of the team involved.

DESIGNING VIKING VR

Composing the Virtual Scenes

As discussed, the camp of the Viking Great Army was a settlement on a huge scale. However, the facts alone give little indication of the human experience of a settlement that has no real modern equivalent. In designing *Viking VR* we were interested in the specifics of human experience, the sense of being there. For example: how did it feel to stand during a winter morning, at the edge of the camp, looking across the uninhabited land beyond, with frozen ground under one's feet and snow beginning to fall. What would one have heard? What movements would have caught the eye? What shapes would have dominated the land? VR seemed a uniquely appropriate medium for conveying not just factual detail but a sense of scale and distance, light and atmosphere: all important factors in creating a compelling experience.

One of VR's strongest suits is its capacity for the spectacular. VR experiences depicting physically large environments are no more difficult or expensive to build than small ones, unlike real-world reconstructions where size and scale are invariably limited by budget and technical resources. This makes the medium uniquely suited to telling stories where scale and spatial configuration are important. In the case of the Torksey archaeological finds, the scale and complexity of the site are particularly difficult to imagine, even with the help of tangible objects from the period. For example, a number of clench nails were found at the site. These rather uninspiring pieces of rusty iron indicate the presence of ships, in fact it is estimated that dozens of ships and boats were moored on the river at the edge of the camp: presumably an impressive sight.

We decided that the best way to approach the project was to use a 3D interactive VR platform to develop 3D vignettes that could be experienced from a fixed point. These vignettes would function as a hybrid between a conventional museum exhibit, highlighting a range of objects to be examined and reflected upon and a living museum in which artefacts could be used as the focus for human activities. The viewers' interaction with the scene would be purely visual: they would be able to look around the scene but not move within it. This would remove a number of health and safety problems and would hopefully make the piece as easy to use as possible. It would also mean that each scene could be arranged carefully to make use of our limited resources and to enable us to omit or obstruct areas of archaeological uncertainty. Without having to support viewer movement, objects in the distance could be simplified while the foreground of each scene could be made in great detail. We also reasoned that the lack of movement would allow us to avoid clearly embodying the viewer in the experience in order to prevent disorientation. Besides removing a number of technical challenges this enabled us to make the piece less specific and more inclusive, avoiding the need to provide a visual representation of the viewer's body that would almost certainly necessitate fixing the size, gender and ethnicity of the viewer. We hoped that the fixed viewpoint would further promote discussion among viewers and a sense of shared experience as each viewer would encounter the same objects and characters.

Over 20 key objects found at Torksey were used as the basis for the vignettes. Given their likely context, these were focussed around specific activities emphasising wherever possible the link between object and human experience. They were composed as follows: -

1. A riverside scene where boats and long ships were moored and where shipwrights and sailors would repair and provision them.
2. A trading scene in a busy thoroughfare, seen from inside the tent of a trader.
3. The workshop of an artisan featuring jewellery and test pieces from which a neighbouring smithy could be seen.
4. A night-time scene where some of the camps inhabitants could be seen telling stories, drinking and playing games.

Linking Archaeology and Reconstruction

Authenticity in every detail was particular important and great care was taken to check each object with the archaeologists in the team. The planning of each vignette began with reference photographs of objects from Torksey and these were used to develop a narrative concept. In each case, a series of questions could then be asked.

- What key points were the vignette intended to illustrate: what did the objects included tell us about medieval life in general and life in the camp in particular?
- What did each object indicate in terms of human activity: what was it used for and by who?
- Most importantly in terms of developing believable coherent and authentic environments: what did each object suggest in terms of its surroundings?

These questions enabled the team to work outwards from the objects, developing environments for them to inhabit.

For example: lead trial pieces, used for testing the stamps used to decorate jewellery, strongly suggest that silversmiths were working at Torksey. Existing research suggests these objects would likely be encountered in conjunction with hammers, anvils, braziers and other tools of the smith's trade. Given the weather conditions in the East of England and the time of year, it seems unlikely that this activity would have taken place fully out-of-doors. All of this information could be used to suggest an environment: a tented workshop, most likely one of many.

This approach enabled a list of corollary objects to be generated and also suggested characters to inhabit each scene. These characters would serve a number of purposes, adding movement and visual interest to the scene while also demonstrating how the various objects were actually used. They could also be used to reinforce environmental details that were otherwise difficult to communicate via the vignettes: stamping their feet in response to the cold, sheltering from the rain.

Each character and object was researched carefully before being modelled. This process involved close collaboration between the 3D artist and archaeologists in the team. Each individual object was discussed and visual references provided for the artist. These could then be worked up into 3D models upon which the archaeologists would then comment and suggest alterations.

The objects were then considered in terms of their spatial arrangement in the vignette. Archaeological and historical evidence could again help with this, suggesting how the camp may have been laid out, from its interaction with the surrounding countryside down to the design and materials of individual tents and other structures. Data was also gathered from the contemporary site: modern-day Torksey is now farmland but was used to provide useful topographical information for the virtual reconstruction. A field trip to the site enabled accurate lighting measurements and colour references to be taken.

Despite our careful research, a number of details had to be imagined or extrapolated from existing research. The exact configuration of the camp is unknown, as are some of the specifics of structures, costume and people's appearances. As discussed, this is a common problem in reconstruction and we addressed it chiefly through the 'framing' (a problematic term in VR) and visual style of the vignettes. Rather than attempting a fully photo-realistic reconstruction of the site (which would be difficult given the constraints of the technology), we decided on a painterly, slightly stylised approach to the visual design of the vignettes. We hoped that by avoiding photorealism and by referencing the aesthetic style both of games and of archaeological paintings we could encourage visitors to maintain a slight critical distance, rather than unquestioningly accepting the truth of every detail of each scene.

We also composed each scene to give an impression of the scale of the camp without indicating its configuration. We avoided wide-open vistas and instead made sure that each vignette gave partial glimpses into the distance, giving a sense of space and scale without detail.

Building the Scenes

To manage the development of each scene, common game design workflows were used. From maps and storyboards, each vignette was 'blocked out', using simple 3D objects in order to give an idea of how the scene would surround the viewer and how objects seen from close range would work against items seen in the distance. 'Paint-overs' were then produced in which colour was added over the blocked out forms exploring how each would appear in terms of atmosphere and lighting.

Next, a script of events was drawn up which included not only character movement and dialog but moving details in the environment: birds overhead, domestic animals moving about the camp, weather effects such as rain. These would be translated into more detailed dope sheets (annotations for animation) and scripts for the 3D artist and sound designers.

The sound design consisted of a combination of both atmospheric beds – generic background sounds for a given scene that were used to build a sense of the sound environment the viewer would be immersed within e.g. rain, fire – and spot effects. The latter were sounds associated with specific visible objects, and so required spatial manipulation to enable the sound to be updated and remain 'fixed' to the object for the duration of the scene. This was in some cases due to specific animation of an object or character in the scene, or due to the viewer changing their perspective on the scene – for instance, a voice being heard from in front or behind the viewer, depending on the orientation of the HMD.

Dialog between characters in period languages was also included, for which linguistics experts provided performances. These conversations were to be perform two purposes: to provide an aural indication to members of the public of the variety of languages spoken at the camp and, for the expert, to refer to activities and topics not addressed directly in the vignettes. For example in one vignette a family sitting by the fire is entertained by the father's account of a raid, while in another, a woman on her way to buy bread compliments a smith on the sword he is forging for a nobleman.

Each scene was modelled, textured and animated in 3DS Max. Finally, all the assets were assembled in Unity. Google's Cardboard Software Development Kit (SDK) was used to implement head tracking via the phone's internal accelerometers and gyroscope and to handle 3D stereoscopic rendering to the phone's display and 3D spatial audio. Unity was chosen as it allows easy integration of 3D graphical and audio assets and very rapid prototyping of VR scenes. Google's Cardboard was chosen as a design specification due to its high uptake and the fact that it works with a large number of devices. Its open specification also meant that a wide choice of headsets was available to use and we could even fabricate our own using Google's dimensions.

One of the drawbacks of using a phone-based VR system was the lack of available computing power for complex lighting and material effects. In fact, the complexity of the scenes meant that no real time lighting could be used. Rather than use Unity's own lighting system, 3rd party renderer Mental Ray was used in 3DSMax to 'bake' lighting information into each scene. This workflow, although complex and time-consuming, allowed far greater photometric control of lighting in the finished scenes. Upon completion, each vignette was exported as an android application for installation on the VR devices.

Hardware Design

In order to adapt our design process to the peculiarities of technical platforms it was important to decide upon the hardware we would use early on. None of the commercially available HMDs we were able to find seemed likely to be robust enough to survive 6 months of constant use. Moreover, all of them had absorbent foam or fabric padding or straps, which had been identified as a health risk.

The lack of cabling also raised the problem of power usage. Running VR applications typically drains mobile phone batteries quickly and, with the museum's limited staffing, it would be difficult to recharge phones during the museum's opening hours. Sound would also have to be taken into account as the piece was to feature high quality audio and period dialog. Conventional headphones would be difficult to use due to health risks and robustness.

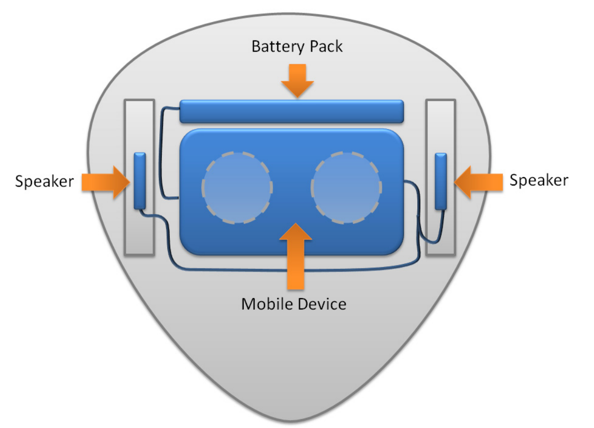

Figure 3: Components within the headset

These requirements suggested that the best approach might be a simple custom casing containing phone, integral headphones and a battery pack to extend the phone's working life. Samsung Galaxy S6 phones were selected as a good compromise between performance and economy (these were the next-to-latest generation of product at the time). These were housed in a laser-cut plywood casing along with Cardboard specification plastic lenses and headphone speakers. A large USB battery pack was also contained in the headset to extend the phone's battery life (see figure 3). With this addition and through developing a simple script that turned off the phone's screen when not in use, we were able to extend the headsets' battery to over 6 hours of continuous use.

The headset was designed to only be opened for charging access at the end of each day. Given that the museum was usually quiet at the beginning and end of the day we predicted this extended life would be enough to cover the museum's 10am-5pm opening hours.

We designed the headsets to be held up to the face for use, rather than being strapped to the head. We realized that by eliminating straps altogether we could not only solve the problems of health and safety and robustness discussed above but we could also encourage a different, less isolating experience. We reasoned that this headset could be easily passed from visitor to visitor, encouraging discussion and the sharing of experiences.

Figure 4: A finished headset

We based the appearance of the casing on a Viking bone mount that was used extensively in the branding of the exhibition (see figure 4). The shape of the headset also referenced seaside tourist binoculars. It was vital to place the experience firmly in the visual context of the exhibition, to ease visitors' transition into the experience while also suggesting the affordances of the HMD. It was also important to disassociate the headsets from potentially intimidating consumer VR technology.

Installation

Viking VR was installed in a small room leading off one of the main exhibition spaces in the Yorkshire Museum. In order to prime the visitor for the type of experience they were about to have, the space was populated with props that were real-life versions of those visitors would encounter in VR. A four-channel surround-sound ambient soundscape consisting of wind noise, birdsong and other sounds from the camp was played at low volume through speakers hidden in the space. Elements of the audio source materials for this soundscape were selected from each of the VR scenes, to key visitors into what they were about to experience, and provide an additional sense of immersion. This ambient soundscape was of the order of 5 minutes long, and designed such that it would not seem overly repetitive or obviously looped to the average visitor who would not be likely to spend a long time within this space. An interpretation panel explained briefly the background to the exhibit. Lastly, a fly-over of a CG reconstruction of Torksey previously made for TV played on a screen in the corner of the space, further placing the vignettes in context.

DISCUSSION: VIKING VR IN ACTION

Viking VR was hosted at the Yorkshire Museum between May and November 2017 with over 75,000 visitors attending the exhibition. Over the course of the show we monitored visitors' experience through a number of measures. We used the museum's own data for simple quantitative information, such as visitor numbers, peak usage etc. Museum staff and researchers also ran a number of observations over an 8-week period and gathered written and verbal feedback. Visitors were asked to complete a brief questionnaire to which 253 sets of responses were collected.

Technical

As discussed, a major concern in designing the experience was reliability, given the exhibition's long run and low level of technical support. Initially the devices experienced a number of minor problems. Our secure design for headsets meant that the phone's touchscreen and buttons could not be used by the public. It was therefore imperative that all notifications must be turned off for all of the applications running on the phones as they would interrupt the display of the VR app and could not be cancelled by staff on the museum floor. In practice, this proved difficult due to the design of the Samsung devices and their native software. For example: encasing headphone speakers within the headset's 'ears' meant that the phone's audio volume had to be automatically set to its highest level by the application in order for the audio to be loud enough. However, this would cause a warning notification to appear on the screen that would then be impossible to dismiss.

We also found that audio in general was difficult to make out through the headsets due to the noisy surroundings of the museum and the distance between the listeners' ears and the headsets' speakers. We noted however that the ambient soundscape within the room did act to provide a suitable auditory experience to support the scenes, even if it was not always possible to perceive aspects of the specific sound design as part of each scene.

Despite including apertures inside the headset for the phones to dissipate heat, we found that these were inadequate and the phones tended to run above normal temperature. Although this was within safe ranges, the phones would automatically take measures to cool themselves, resulting in a slight but noticeable drop in frame rate. This was partially solved by a modification to the headsets that introduced larger apertures into the headset and further mitigated with our development of an app to automatically turn off the VR application between viewings but the phones were found to be extremely sensitive to temperature. Despite these initial problems, the devices functioned well throughout the exhibition and required very little maintenance. Crashes of the application were rare and we found that the external battery packs meant that each device could indeed run without needing to be charged during the museum's opening hours.

Visitor Experience

During the exhibition of the work we were interested in the individual experiences of visitors encountering the VR exhibit, specifically with reference to how they engaged with the headsets and through them the vignettes. The novelty of VR was commented upon: of the 253 visitors canvassed, 62% had not used a VR headset before. Interestingly, their comments were often specifically about content rather than the technology involved or the experience in broader terms.

Visitor responses were generally very positive (in response to the question 'How did the headsets make you feel? How is this different from your previous museum experiences?' 83% of visitors gave positive feedback). Many visitors commented positively on the sense of immersion and expressed surprise at the scale of the camp and the everyday activities taking place. Visitor comments suggested that some of the specific features we had included were interpreted in the way we hoped. For example over 10% of responses reflected on how cold it must have been in the camp: visitors discussed how this must have affected the lives of the camp's inhabitants, their clothing and dwellings. Particularly interesting were the social aspects of the experience. Far from a solitary experience, visitors used the headsets to discuss what they were seeing with their friends and families, drawing attention to specific features and making connections between the activities in each vignette.

Interestingly, despite the wealth of design guidelines on the importance of maintaining a high frame rate, less than 4 percent of visitors asked reported any dizziness or other ill effects. This may well be due to the design of the headsets and the fact that they were not used for more than a few minutes at a time.

The relationship of the headset design and installation to the content of the vignettes was commented upon by a number of visitors with several drawing attention to the appropriateness of the wooden surfaces and how this linked to the natural materials simulated in the VR spaces. However the weight of the headsets was commented on by several visitors, especially with regard to children using them. Particularly interesting was the fact that 4% of visitor responses remarked on the smell of the wooden headsets, many equating it with wood smoke from the campfires in the vignettes. This was not a planned feature of the exhibition and was due to the laser-cutting process used in the fabrication of the headsets. Even visitors who worked out the reason for the smell commented on how it increased their sense of immersion: indicating the willingness of viewers to suspend disbelief and immerse themselves in the vignettes.

Designing for VR in Cultural Heritage Settings

A notable design challenge was working within the constraints of the phones' processing power. The lack of real-time lighting and shadows posed a particular challenge for animated content meaning the movement of characters in relation to light had to be carefully limited. For example, most of the dialog within the vignettes was between people standing relatively still. In other scenes this was not a problem due to the type of lighting in the scene: the horse and rider in the background of the scene below (see figure 5) are pre-lit but as the grey, rainy ambient light is flat and low in contrast, the effect is still credible.

Figure 5: Pre-lit characters in the vignettes

We found that stereoscopic 3D lent itself particularly well to leading the eye through the scene and made configurations of space that would have been confusingly complex on a 2D screen perfectly easy to understand. As each of the vignettes were seen from a fixed point, this meant that we could create what we hoped were intriguing configurations of space which would also help keep each scene within the constraints the devices' processing power. For example, the impression of rows of tents extending into the distance could be maintained by culling invisible parts of each tent from the scene.

The high dynamic range possible due to the high contrast ratio of the phones' screens and their proximity to the viewer's eye meant that we could use light to fine tune which objects or sights would draw the eye. This was very effective in fire-lit scenes, where far greater contrast could be achieved between light and dark areas than would be appropriate on a flat screen (see figure 6). This enabled us to draw attention to features of the camp that visitors might not otherwise consider, such as the contrast between the bright lamp-lights of the tented areas at night and the darkness of the surrounding countryside.

Although it was relatively simple to establish a workflow through which artists and experts could collaborate in developing individual objects, it was far more difficult to develop and assemble the scenes collaboratively. We attempted to plan each vignette through maps of the scene but found that these could provide only the most basic indication of what the user could see. As each scene was blocked out, it became more difficult to communicate what it felt like to inhabit and could only be meaningfully understood and discussed using an HMD. We attempted to use 360-degree video and stills from multiple viewpoints but even these were of little help, missing as they did the differentiation between foreground and background objects apparent in the stereoscopic 3D scene.

Figure 6: A firelit scene.

CONCLUSIONS

Viking VR involved applying game design techniques and design approaches from the growing VR community along with more traditional archaeological and curatorial conventions to the design of a Cultural Heritage exhibit. As such it represents, among other similar projects, a first step in exploring a number of specific aspects of VR design for Cultural Heritage and raises interesting questions for future research.

Design Approaches and Workflows

We found that the design process and production workflow used worked well in enabling the type of planning discussion and detailed expert fact checking needed in a reconstruction project. Using Interactive 3DVR meant that assets could be developed, discussed and adjusted long after final decisions would have been necessary for a CVR piece. In this case, this flexibility was of more benefit than would have been offered by the greater level of photorealism offered by CVR. We also found that planning the configuration of immersive 3D scenes was extremely difficult to accomplish collaboratively. As VR technology becomes more ubiquitous, collaborative discussion using multiple headsets and multi-user VR spaces might enable design teams to overcome this significant obstacle.

Using relatively inexpensive mobile devices in simple fabricated casings also worked surprisingly well even in the difficult circumstances of a long exhibition in a busy museum. A longer testing period might have assisted in identifying potential problems with heating and sound reproduction.

As with any media piece, the detail and complexity of the scenes were limited by a combination of the skill of the artists involved, the time and resources at their disposal and the limitations of the technical platforms used. The technical development of the scenes was a highly skilled craft process and relied on the expertise of experienced sound designers and a 3D artist. Possibly, as VR gains in popularity, software solutions will emerge that enable museums and Cultural Heritage organisations to develop their own content more easily. However, the high production values necessary for historically accurate work suggests that skilled specialists will continue to be a necessary part of successfully realizing this type of production for the foreseeable future.

Interaction and Embodiment for VR in museums

Viking VR used the simplest type of interaction imaginable in a VR environment: gaze from a fixed point. However, many other types of interaction currently remain unexplored in this context. Gaze-based interaction with objects and scenes is currently possible with mobile technology and could be integrated into vignette-based approaches such as *Viking VR*. At the very least, these could be used to ensure that viewers do not miss important or interesting content, for instance: by allowing the exhibit to check if they are looking in the right direction before launching an animated element.

Our fixed-viewpoint approach and lack of interactivity was limited in terms of how objects could be experienced at close range. A different approach, possibly using spatial tracking would allow users to walk around each space, to examine objects closely, achieving a more accurate and potentially more compelling experience of space and scale. This is currently not feasible using wireless devices alone (although a new generation of devices to be released in 2018 aim to overcome this limitation) and would require carefully managing the physical space of the exhibition in order to keep visitors safe.

This approach would also certainly necessitate a different approach to the user's embodiment in the environment. The most conceptually straightforward approach to this - placing the user's viewpoint above an articulated CG body the movements of which correspond to those of the user - would require careful consideration. The designer must consider not only how the user's 'body' interacts with the environment in a mechanical sense but how this manifestation might affective the narrative coherence of the piece. This would certainly involve addressing questions of period and style but in many cases might also necessitate considerations of gender, ethnicity and differing abilities.

Interestingly, despite the limited interactivity, many viewers described a sense of having felt present at Torksey and expressed a range of physical reactions to the place. From an archaeological perspective this is highly significant because it seems to imply a very different set of psychological responses are at work than we have come to expect through the use of 2D renderings of 3D computer graphics. Further work is needed to understand how VR environments are perceived by users and what impact this might have on the design of future museum exhibits and the future of archaeological representation.

FUTURE WORK

All of these enhancements require careful consideration and not just in terms of how to technically implement them in a way that works with technical platforms and is safe for viewers. In future projects we intend to explore how curatorial techniques can be used in conjunction with game design and cinematic conventions to explore room-scale experiences. We also plan to investigate new ways of interacting with heritage reconstructions using existing and custom controllers. We hope that the resulting knowledge will contribute to an increasingly refined and purposeful set of design guidelines for VR development in Cultural Heritage settings. By pursuing these goals as interdisciplinary concerns, VR can truly become a tool for historical and archaeological communication and exploration.

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