Space on Earth: Assessing the Feasibility of Virtual Reality and Mixed Reality for a Visitor Experience

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Abstract
There is growing interest in using mixed and virtual reality in galleries, libraries, archives, and museums. This paper assesses the feasibility of situating such technologies in the visitor experience at Goonhilly Earth Station. Insights were gathered through three focus group studies conducted early in the design phase ($N = 25$), and questionnaires at three prototype showcase events ($N = 72$). This data reveals enthusiasm about the potential of immersive technology and willingness to pay for premium quality experiences. However, several considerations emerged, including: differing preferences and reservations between key audiences; the need to holistically package the experience; further consideration to encourage social interaction; and the need to address friction when using multiple technologies. Installation designers working with immersive technologies for visitor experiences should consider such concerns to enrich the quality of the visit.

CCS Concepts
•**Human-centered computing** → **Mixed / augmented reality; Virtual reality;** *Empirical studies in HCI;* •**Social and professional topics** → Informal education;

Author Keywords
augmented reality; mixed reality; virtual reality; GLAM; HCI, feasibility study; requirements; attitudes.

Figure 1: Ship. 🅭🅯⊜ Phoebe Herring.

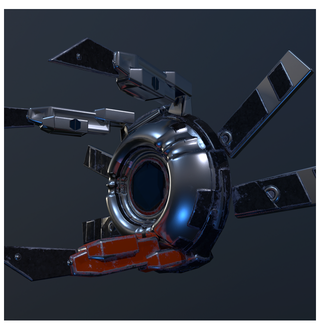

Figure 2: Drone. 🅭🅯⊜ Phoebe Herring.

Introduction

Immersive technologies, including virtual reality (VR) and mixed reality (MR), are becoming more mainstream. The International Data Corporation has predicted further growth in the application of immersive technology from $\$\ 18\ bn$ in 2019 to $\$\ 250\ bn$ by 2021 [6]. Furthermore, the technology is moving beyond just scientific and military applications into education, art, culture, and the humanities. In particular, there is growing interest in the use of immersive technologies within GLAM spaces (gallaries, libraries, archives, and museums). Roussou [12] reported such trends as early as 2001 when the technology was adopted for the *Magic Screen* installation at the Foundations of Hellenic World in Athens. Going on to predict that immersive experiences would become more prevalent in heritage contexts as the technology matured. With examples such as 2016's the *Story of the Forest* in Singapore's National Museum to, more recently in 2019, *The Life* at the Serpentine Gallery in London, both highlighting the increasing maturity of the technology.

However, as Montgomery notes [9], key questions for owners of GLAM spaces include the potential impacts of the technology and return on investment (RoI):

> It is not easy [for museums] to measure RoI to determine whether you are increasing footfall through the introduction of immersive technical features. It's all about the overall visitor experience which is hard to measure. It's the same with all creative content. You never really know if it is going to be effective until an audience experiences it.

This paper describes a feasibility study conducted at Goonhilly Earth Station, a large radio-communication site located in Cornwall, England. The aim, being, to develop a new visitor experience using immersive technology to facilitate a visceral experience of what it might be like to live and work in space. The installation aims to leverage a combination of haptic and audio-visual interfaces, with elements of projection, virtual reality, and mixed-reality, to enable a multi-user simulated experience.

This is situated as part of a larger endeavour in Cornwall to develop and support a burgeoning 'tech tourism' sector. The growth, of which, will be aided through building expertise in and infrastructure for immersive media design. In particular, packaging and deploying emergent immersive, haptic, and computing technologies, as well as new digital platforms, for utilization across the heritage sector at the local, national, and international level.

Three key questions are addressed:

1. What sentiments do Goonhilly's audience have towards the use of immersive technology?
2. Is there sufficient willingness to pay for immersive experiences?
3. How could the design of the future visitor experience progress beyond the prototype stage?

Insights from this research will build expertise in deploying immersive experiences in GLAM spaces. Using human-centred methodologies to understand audiences and clarify expectations will help the sector to unlock the considerable power of immersive technology to enthuse visitors. Such insights can inform the creation of meaningful and vivid interpretational applications that will extend and enrich visitor experiences as well as help heritage sites get the most out of the assets and collections that they hold.

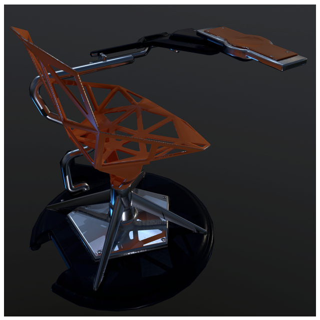

Figure 3: Chair. 🅭🅯⊜ Phoebe Herring.

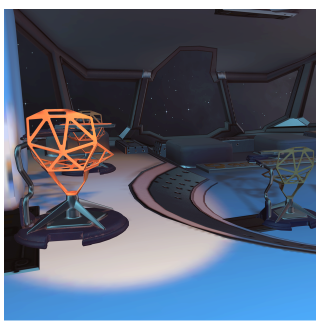

Figure 4: Bridge. 🅭🅯⊜ Phoebe Herring.

Background

There is considerable prior research into immersive technology (e.g., [13, 15, 14]) and many examples of its use in GLAM spaces. For example, in the 1980s NASA were experimenting with a stereoscopic, head mounted display (HMD): the *NASA VIEW System*. Their hardware is similar in form and function to present-day mainstream headsets such as *HTC Vive*.

There was significant interest in technology and design to support immersive experiences in 1990s [7]. This included developments such as cave-based automatic virtual environments (CAVEs), which surround the player in sound and projections, through to wireless haptic controllers, which emulated the proprioceptive feedback experienced when interacting with real objects. However, few offerings based on these technologies were commercially viable.

It was the maturation of mobile technology that paved the way for immersive innovation. Crisper, higher resolution screens and better sensors for tracking movement fed directly into the design of the next generation of head-mounted displays such as the *Oculus Rift* and *PlayStation VR* in 2016 [3]. More powerful hardware capabilities and enhanced mobile operating systems have now led to standalone headsets such as *Oculus Quest*, *HoloLens*, and *Vive Cosmos*.

The question facing curators who wish to develop successful, innovative installations in their GLAM spaces is whether the use of immersive technologies now forms a viable proposition. However, to address this question, the spectrum of immersive technologies needs to be considered. Figure 5, illustrated by Milgram and Kishino [8], defines a continuum of experience that combines the real and the virtual. Such combinations of the real and the virtual span different parts of a "continuum of virtuality",

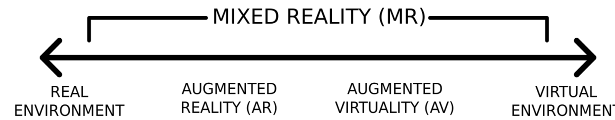

Figure 5: Reality Continuum

whether these are real spaces that have been augmented with virtual assets (augmented reality), or virtual spaces that have been augmented with real-world artefacts (augmented virtuality). Typically such augmentation is supported by a "system that has the following three characteristics: combines real and virtual; is interactive in real time; is registered in three dimensions" [2].

The diverse landscape of innovative technology available affords vast opportunities for curators of GLAM spaces to showcase their collections in many novel and wondrous ways. It has long been known that immerse experiences have the ability to produce the, "feeling of 'presence' naturally [...] allowing for more complex social interactions and designed learning experiences and role plays, as well as encouraging learner empowerment through increased interactivity" [4]. With this in mind, however, it is important to explore which technologies and in which combinations are fit-for-purpose and can achieve this sense of presence.

This offers a compelling opportunity to the heritage sector as curators want to provide visitors with such experiences and ways to engage with their collections. However, many heritage sites are outside major economic hubs, which represents a barrier. A recent report from ImmerseUK [5] suggests that, 'Immersive is already an economic reality in the UK' but that the majority of business activity is based in London (38%). However, there is a skills deficit and as a consequence, the majority of immersive tech 'hot spots' are based in and around major cities. The most recent Rural Development Conference highlights the need to readdress the balance stating, 'The digital-territorial divide must be overcome quickly'[1]. Any installation needs to offer high quality, headline grabbing immersive experience to raise awareness of the opportunities afforded by immersive experiences embedded into the rural landscape of Cornwall.

To achieve this, however, there are further challenges. Among others, these include: assessing commercial feasibility in terms of requirements and cost; documenting best practice; devising interaction blueprints that inform the way such installations might be experienced by different visitors; supporting the ability for non-specialist staff to use and update content; and identifying challenges with use of the technology. Much of this needs to be addressed through original primary practice-oriented research owing to recent fidelity and affordability of immersive technology and the unique contexts offered by GLAM spaces in Cornwall.

Methodology

For this pilot project, a multidisciplinary development team, consisting of the authors from the Games Academy at Falmouth University, produced two deliverables: (i) a ludic sketch, outlining an initial design for the immersive installation and its key mechanics; and (ii) a prototype of the experience, representing a vertical slice of one potential mode of gameplay. The development life-cycle was structured according to agile principles, with the team devising a sprint for the development of the ludic sketch, followed by two sprints for the prototype.

To inform the prototype, a workshop was held at the start of the project to identify target audiences. Relevant stakeholders helped to devise a set of personas, which were then used to inform the design. Following the workshop, three focus groups were organized. Each, coinciding with the end of a sprint to collect interim feedback on the ludic sketch and prototype.

Operating in parallel were showcase events. The ludic sketch was shown at one event, whilst the prototype was showcased at two events. Respectively, these were: the Penryn venue of the 2019 Global Game Jam; the opening of Falmouth University's Creative Bridge; and the Game Art exhibition at The Poly in Falmouth. The purpose of these showcases was to gather insight from people who might potentially visit the Goonhilly Visitor's centre to feed into the design process and the requirement specification.

Qualitative data were collected as notes made by the research team during the focus group studies. These were conducted following the think aloud protocol, involving seven-to-eight participants. Think aloud is an approach that involves asking your participant to use the system in question and verbalise their thought process as they do. Little guidance or prompting is given as the user finds their own path through the given system is typical, though in this case prompts were given to focus attention on pertinent questions or parts of the prototype. According to Nielsen [10], this approach, 'serves as a window on the soul, letting you discover what users really think about your design'. This enabled the research team to gathering fast, informal insight into sentiments that players held towards the prototypes early, as they were being developed. Whilst quantitative data were collected by an electronic questionnaire circulated at the showcase events. The questionnaire was composed of multiple-choice questions and Likert-style items. These were analysed from a frequentist perspective. These studies were subject to the approval of the Falmouth University Ethics Committee.

Research Artefacts

This study is a pilot and, owing to the short development time, rapid prototyping techniques were key. Several low- and medium-fidelity artefacts were produced. These were: a collection of personae; a ludic sketch; a set design; a game design document; and a set of modest prototypes using VR and MR technology.

Personae

Defining the audience for the visitor experiences and segmenting it into a number of personae, or fictitious profiles, helps ensure each market segment is adequately represented throughout the design process. To this end, four primary persona were developed:

1. *Noah Davies (13)* - Young gamer and streamer. Interest in science and motivated by extrinisic rewards. Desires challenge, novel technology, and a clear sense of progression.
2. *Kenneth McCarthy (56)* - Retired engineer, with impaired mobility. Wants to engage young associates (such as family) in learning, ease of use, and a way to instill excitement for STEM subjects.
3. *Anika Chettiar (23)* - Business analyst, passionate about space. Expects paid-for experiences to be novel and exciting. Familiar with technological pitfalls, but likes to see systems that push what is possible.
4. *Ada Morgan (38)* - Experienced DevOps engineer. Enjoys role-playing games that are grounded in historical accuracy. Desires sense of wonder, and narratives that evokes thought and reflection.

These were adapted and expanded upon throughout the prototyping process. A further six were created.

Set Design in VR

The design of the space in the visitor's centre was then proposed. This took the form of a pre-visualisation mockup of the bridge of the fictitious spaceship *Prydwyn* (Figure 1) in VR. This allowed for the intended real visitor attraction environment to be explored by stakeholders.

The layout (Figure 6) takes inspiration from well-known science fiction tropes in film, television and games, such as demonstrated in *Star Trek: Bridge Crew* [11]. Emulation of what would be seen through the 'windows' was also incorporated. In its present form, the bridge accommodates up to eight visitors at functionally identical 'stations' based on the chairs (Figure 3). The intent is to use a dynamic theatrical model that encourages people to enter the magic circle and suspend disbelief.

In the 'real world' bridge:

1. All stations have identical control schemes and access to immersive technology.
2. Players wear head-mounted displays.
3. Players choose their station dynamically, irrespective of physical position.

Attached to each chair are standardised and simplified input devices. A trackball-orientated interface is deployed for two key reasons. Firstly, visitors are unlikely to be dedicated game players. So, simplifying the controls make them easy to learn. Secondly, wear and tear of equipment used in a public space is a concern. The physical actions of interacting with dedicated (and expensive) controllers and headsets would be problematic, but using a simple world-grounded device could offset this.

Ludic Sketch
A ludic sketch is an abstracted prototyping technique used in game design. Game mechanics are quickly 'sketched' in a game engine to formulate and test gameplay. Such sketches are not usually playable, but have sufficient interactivity to be illustrative. Assembling sketches forms a more coherent vision that informs further development.

For this project, sketches were made for each role on the ship. During a scenario, visitors assume whichever role is required. These include:

- Pilot, who controls the ship by programming maneuvers and burns
- Scavenger, who pilots a drone to prospect and collect resources in the surrounding space
- Defence Officer, who ensures the ship is protected from debris by balancing power across shield technologies such as magnetized plating
- Turret Control, which protects the ship from threats such as drifting debris
- Engineer, who is responsible for managing the resources, building new drones, and repairing the ship's systems
- Communications, who is responsible for dealing with messages from mission control and other parties involved in the scenario's narrative.

The ludic sketch was implemented in C# using Unity $2018.2.20f1$, and implements illustrative gameplay for all of the roles. It was used to accompany the prototypes during the focus group studies and at showcase events.

Game Design Document
Following the ludic sketch, a design document was assembled. This outlined all the core interactive elements of the intended experience. It also includes elements of world building and narrative generation, notably:

> '99942 Apophis' is a 370-meter near-Earth asteroid that was the first to reach Level 2 of the Torino Impact Hazard scale. Observation suggests a 1 in 150,000 chance of a collision with Earth in April 2068. Goonhilly Earth Station and the Prydwen become part of a mission to investigate the asteroid. First step, establish deep-space communications to support drone operations.

This context introduced the notion of using remote semi-autonomous drones (Figure 2) to grant visitor's agency in-and-beyond the spaceship; thus, expanding the potential scenarios that could be offered in the future.

Immersive Prototypes
Two prototypes were developed, offering very modest vertical slices of the gameplay. They both focused upon the turret control role. The first was developed using *Steam VR* for *Oculus Rift*, whilst the second was developed using the *Microsoft Mixed Reality Toolkit* for *HoloLens*.

The use of mixed reality technology demonstrated an alternative approach to what is already available on the market (i.e., [11]). It evidences the possibility that a blended approach could ultimately offer greater excitement for visitors, help to facilitate social interaction, and offer more than a simple at-seat experience. These prototypes were also used to explore questions about interaction design.

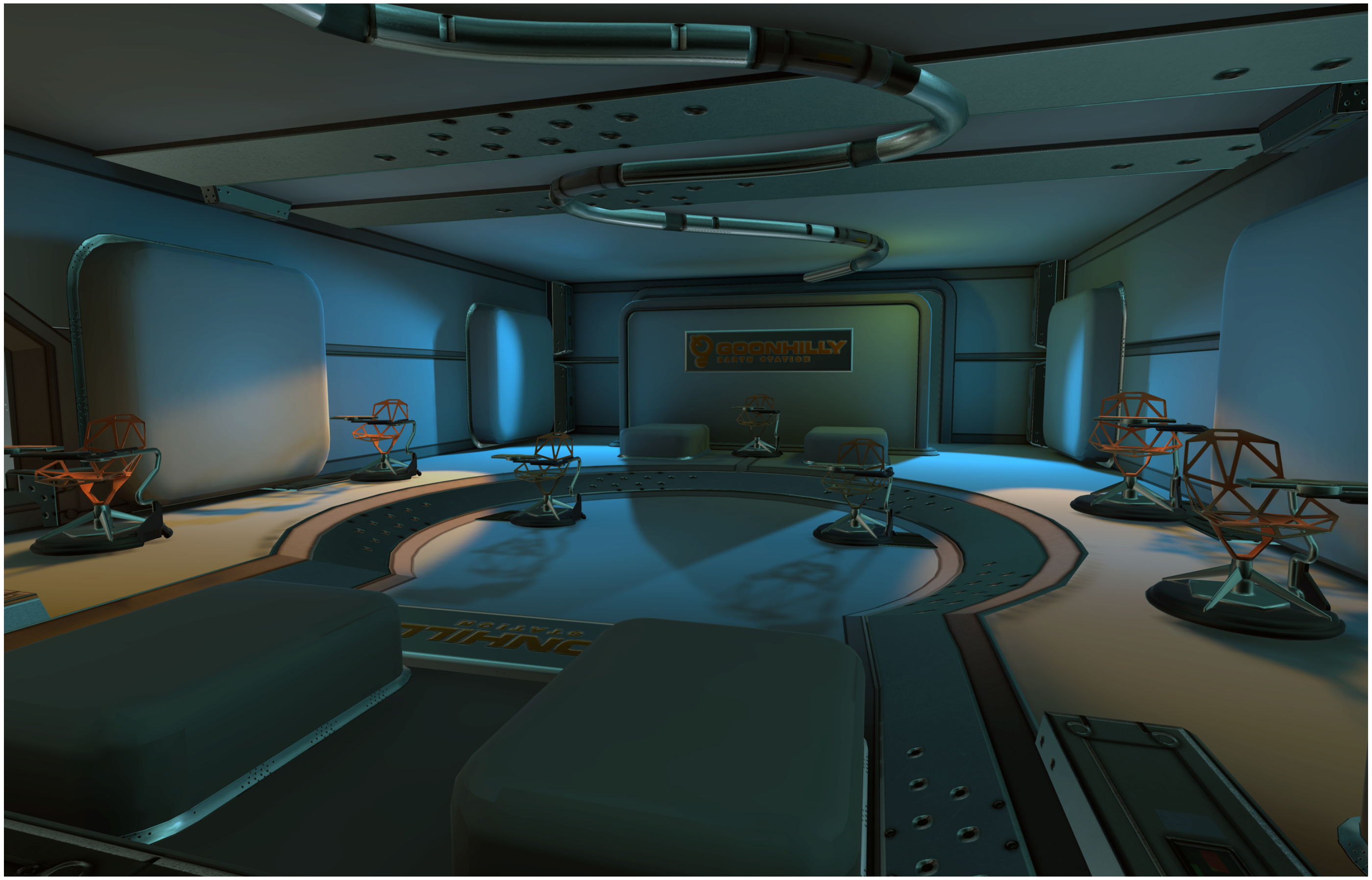

Figure 6: A virtual reality mock-up of the bridge of the *Prydwyn*, the ship designed during our world-building exercises. It is the intention to replicate this design (or an adaptation thereof) as a physical installation as part of the Goonhilly Earth Station Visitor Experience. Credit: Phoebe Herring.

		Familiarity		Interest	
Sector	*N*	*MR*	*VR*	*Games*	*Immersive*
Arts	9	7	8	8	9
Business	3	3	3	1	2
Education	5	4	5	4	5
Games	14	6	11	11	14
Retail	2	1	2	1	2
Technology	5	5	5	5	3
Undeclared	34	10	25	22	28
All	72	36	59	52	63

Table 1: Breakdown of the sample by sector of work/study, showing familiarity with mixed reality (MR) and virtual reality (VR) alongside interest in games and immersive experiences.

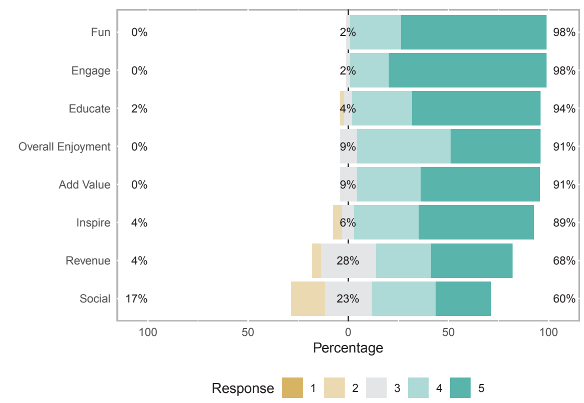

Figure 7: Sentiment towards immersive technology

Analysis & Results

The sample consists of 72 people, drawn from members of the public at showcase events. Data were analysed using R version $3.5.2$.

Descriptive Statistics

The mean age of participants was 23.11 years, with a standard deviation of 7.71 years. This ranged from 16 to 56 years of age. There were 50 men (69.4%), 20 women (27.8%), and 2 who identified as other. Most of the sample were local to Cornwall (50%), with some visiting from outside Cornwall (27.8%) or otherwise undeclared. Most of the participants were degree educated (52.7%), with 9 high school students and 6 college students (20.8%). The rest were undeclared. Only a small number declared that they were able to drive motor vehicles (26.4%). Table 1 shows a breakdown by sector of work or study. This shows that most of the participants were already familiar with virtual reality, but only half had previously used mixed reality.

What sentiments do Goonhilly's audience have towards the use of immersive technology?

Figure 7 illustrates that sentiment towards the use of immersive technology in the visitor experience is positive. The prototypes were described as 'fun', 'engaging', and having the potential to 'educate'. Additionally, participants 'enjoyed' the experience, agreeing it would 'add value', as well as 'inspire' interest in science, technology, engineering, or maths (STEM). There were, however, reservations about generating revenue and uncertainty surrounding its social elements.

The focus groups suggested that the way in which the installation is packaged together with the overall visitor experience is critically important and needs to offer 'substantial premium' if additional payment is demanded. Additionally, there was skepticism around the collaborative and social elements of the installation, and how this fit in with the broader goal and vision of the visitor experience.

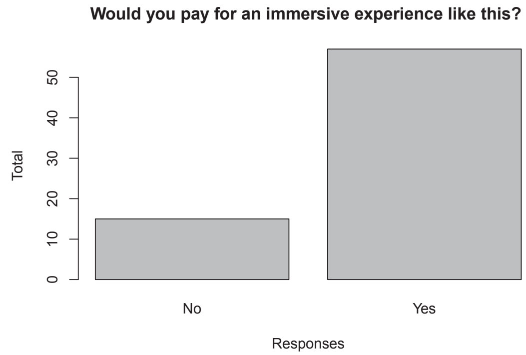

Figure 8: Proportion of participants willing to pay for an immersive experience at Goonhilly Earth Station

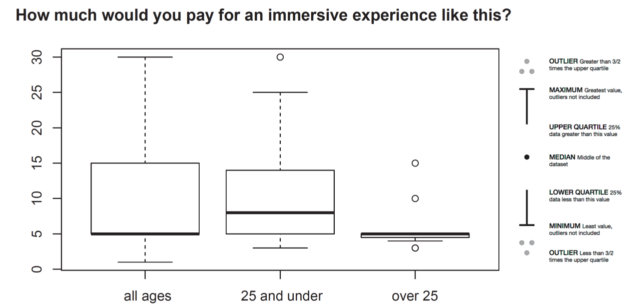

Figure 9: Tukey boxplot showing amount of money ($\pounds$) that participants would pay for an immersive visitor experience. Black horizontal bar indicates the median, the box indicates quartile range, and whiskers indicate range. Dots indicate outliers.

Is there sufficient willingness to pay for immersive experiences?
Despite apparent reservations about revenue generation, there is considerable willingness to pay for an immersive experience at Goonhilly, with 79.2% of participants agreeing that they would 'pay for a space exploration experience like this'. This is a strong endorsement for the project overall. The mean amount that people would pay was $\pounds\ 9.54$ with a standard deviation of $\pounds\ 6.66$. This ranged from $\pounds\ 1$ to $\pounds\ 30$ per person assuming a $1-$hour experience.

The focus groups suggest there are many caveats and requirements attached to this endorsement. Notably, the quality and scale of the final installation. They also suggested packaging it with the wider visitor experience.

There were no correlations between willingness to pay and demographics observed. People from every sector, except those working in technology, were interested in immersive experiences. The only predictors of willingness to pay are prior interest ($r = .220, p = .06$) and being in the technology sector ($r = -.263, p = .02$).

However, although a correlation between amount willingness to pay and age isn't confirmed ($r = -.315, p = .07$), the data shows a clear divide. Segmenting the data set into those 25 and under and those over 25 revealed the difference ($t = -2.422, df = 32, d = -0.85, p = .02$) as shown in Figure 9.

These findings suggests that appealing to a younger audience of people who work outside of the technology sector could form a viable strategy. A price point above $\pounds\ 10$ per person for an experience lasting about $1-$hour is not amenable to a large proportion of those surveyed. It is worth noting that that the 'quality' and 'premium' of the final version will likely have an impact on price point.

How could the design of the visitor centre progress beyond the prototype stage?
Overall sentiment was positive, with many endorsements. Particularly, for the asteroids gameplay. Participants were happy with the direction of the development. They also suggest how to progress beyond the prototype stage.

Figure 10: Think-Aloud protocol data cluster

Figure 10, a cluster analysis in VOSViewer, does not evidence any distinct clusters. This is unsurprising given the small sample size. Nevertheless, thematic analysis using inductive coding highlights several considerations to:

- more clearly define and coordinate each role;
- balance the roles to ensure each player has an engaging experience;
- explore how players could better collaborate;
- consider a bridge design which includes more ‘windows’ out of the ship;
- address the perhaps too sparse, homely, and clean a feel as well as add more equipment;
- consider a smaller bridge for four or five players;
- maintain the overall aesthetic and sci-fi context;
- deliver a ‘AAA’ level of audio-visual quality;
- and consider granting ‘early access’ to playtest a more complete prototype.

Conclusion

This paper presents a ludic sketch, a set of personae that define the target audience, a physical set design (with particular attention to a chair providing haptic feedback), a game design document, a prototype, and market insight for a new installation at Goonhilly Earth Station in Cornwall, UK. Collectively these artefacts form a feasibility study which demonstrates the potential for immersive installations, implemented using a blend of virtual reality and mixed reality technology, in a visitor experience. The findings suggest a willingness to pay for ‘premium quality’ immersive experiences, lending support to new business models.

Immersive installations have the potential to attract visitors, despite the remote rural location of sites like Goonhilly Earth Station. Sentiment towards the use of immersive technologies in GLAM spaces is positive. The success of immersive installations, however, will be reliant on the ‘premium’ that the technology offers and the level of engagement achieved through a compelling narrative, fun and balanced gameplay, along-with a visitor journey that is packaged together in order to feel coherent and authentic.

Acknowledgements

This pilot study was made possible due to funding from Innovate UK, part of UK Research and Innovation (UKRI), from the *Audiences of the Future: Design Foundations* programme (Grant #133759).

This project was also supported by Bird & Gorton Consulting who organised and facilitated two workshops on human-centred design as part of the project.

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Abbreviations

AR Augmented Reality

CAVE Cave-based Automatic Virtual Environment

CCS Computing Classification System

GLAM Gallaries, Libraries, Archives, and Museums

HCI Human-Computer Interaction

MR Mixed Reality

STEM Science, Technology, Engineering, and Mathematics

UK United Kingdom

VR Virtual Reality