



Shaun
the
Sheep®

IMMERSIVE

A report produced by the University of
Liverpool for Aardman. April 2023

★
AARDMAN



Contents

Foreword	3
Meet the Team	4
Project Overview	10
<i>Rationale & Wider Research/Industry Context</i>	
<i>Principle Research Aims & Activities</i>	
<i>Research Questions & Methodology</i>	
<i>Potential Beneficiaries of R&D Project</i>	
<i>Immersive Experience: A Dialogue Between Space & Narrative</i>	
I. Target Audience	20
<i>A Chinese Audience</i>	
II. Story Development	22
<i>From Linear to Realtime Interactive</i>	
<i>Branching Narratives</i>	
<i>Specific Challenges</i>	
<i>Technical or Creative - which comes first?</i>	
III. Dynamic Content Creation	27
<i>Context</i>	
<i>Realtime Workflow</i>	
IV. Spatial Setting	29
<i>COVID-19 Pandemic: Impact on Developing/Testing a Location-based Experience</i>	
<i>3D Reconstruction & VR simulation of XR Lab Space/Auditorium</i>	
<i>Immersive Theatre Layout: Seating & Spatiality Development</i>	
<i>Free Roaming Investigation</i>	
V. Game and Interaction Design	42
<i>Collecting Human Data</i>	
<i>The challenges of designing interactions with an unpredictable audience</i>	
<i>Interaction Framework</i>	
<i>Overt Audience Interactions</i>	
<i>Audience Movement Tracking</i>	
<i>Machine learning and Interaction</i>	
<i>Key Objectives of Interaction Scenario</i>	
<i>Realtime Participation Scenarios (Overt)</i>	

<i>Interactive Rope Pull</i>	
<i>Vertical Descent</i>	
<i>VR Simulator of Large Scale Multi-person Immersive Installations</i>	
<i>VR Audience Testing</i>	
<i>Distortion & Immersion: Down Movement</i>	
<i>Audience Movement & Distortion</i>	
<i>Character Engagement and Immersion</i>	
VI. Remote Experience	64
<i>Project Scope and Deliverables of the Remote Experience</i>	
<i>Sprint 1: Discovery Phase: Accidental Sheep Delivery Service (ASDS)</i>	
<i>Sprint 2: China Context</i>	
<i>Sprint 3: China and technical validation of sharing element</i>	
<i>Sprint 4: Technical Validation of Game Element</i>	
<i>Sprint 5: Creative Validation of Game Elements</i>	
<i>vSprint 6: Sheep & Greet: Final Creative Prototype</i>	
VII. Spatial Sound	86
<i>The Role of Sound in an Immersive Environment</i>	
<i>Spatial Sound Settings and Materials:</i>	
<i>The Application of Spatial Sound in Realtime Environments</i>	
VIII. Outcomes	89
Presentations	91
References	92

Report Authors

Professor Richard Koeck

Rachel Cummings



Contact Us

rkoeck@liverpool.ac.uk





Foreword

By Richard Koeck

Shaun the Sheep: Immersive Experience is one of eight large-scale UK-China research-industry Creative Partnerships launched in February 2020. These projects are focused on collaboration between higher education institutions and industry partners in UK and China in areas including sustainable fashion, gaming, the performing arts and immersive experiences in cinemas and museums. Despite operating against the backdrop of a worldwide pandemic and a fluid political climate, this unique programme is seen by many working in and with creative industries as a huge success, which now, in 2023, is entering its next phase with the creation of a UK-China Creative Industries R&I Hub in both countries.

Shaun the Sheep: Immersive Experience was conceived as an idea by Prof Richard Koeck, University of Liverpool and Heather Wright, then Executive Board Director and Partner Content at Aardman, during a fantastic UKRI delegation visit to Shanghai in 2019. Both were drawn to the idea to come up with a piece of innovation and resulting audience experience that no other entertainment company has developed before. Furthermore, both saw the opportunity to directly work with colleagues from the Shanghai Theatre Academy (STA) in the UK and China and to build up a strong partnership relationship, for instance around XR technologies.

During our funding period, which officially ends in April 2023, the project leaders had to deal with many unforeseen circumstances, which often required an agile management, quick and decisive responses to emerging and pivotal situations. The support from the AHRC and its representatives throughout this project has been outstanding and is worth a particular mention. Not all our original goals could be fulfilled. However, two things never changed.

Firstly, our ambitious goal to deliver a world-first in research innovation that would have the potential to transform the delivery of Aardman's high-end animation work from a currently linear and pre-rendered end-user product into a ground-breaking, non-linear, realtime, responsive, spatially immersive experience; one that can be enjoyed by a wide family audience and recognising China's cultural context and values in the realisation of this work. We believe a significant impact of this project can already be seen.

Secondly, it was impressive to see such a high level of commitment towards this unique and challenging project from start to finish and from all partners. During all ups and downs, we were able to hold the team together, in the most difficult of situations, and come out with a sense of being stronger on the other end. I think this was also possible due to the extremely friendly, inclusive, and professional atmosphere that working with a company such as Aardman has brought to our project.

This has been an amazing R&D journey supported by UKRI and the AHRC, which we think is worth reporting on. The results will hopefully translate into a built, commercial product in China or elsewhere and have a positive impact for Aardman and on similar immersive experience projects, which undoubtedly are in the pipeline and will see emerging in the coming years.



Meet the Team

The Shaun the Sheep: Immersive Experience project required a multidisciplinary team of experts from the fields of architectural design and visualisation, immersive design, animation, virtual reality, realtime technologies, machine learning, spatial sound, webAR, and commercialisation. The team consists of academic leads in the UK and China, industry partners and a group of people that is situated between creative technology and research.

Please meet the team!

PROJECT INVESTIGATORS

RICHARD KOECK

University of Liverpool, r.koeck@liverpool.ac.uk

Principle Investigator, Architecture and Visual Arts

Richard is Professor and Chair in Architecture and the Visual Arts at the *University of Liverpool* and Director of the *Centre for Architecture and the Visual Arts | CAVA*. He holds a professional degree in Architecture (Germany) and two postgraduate degrees in Architecture and the Moving Image (UK).



SYLVIA XUENI PAN

Goldsmiths University, x.pan@gold.ac.uk

Co-Investigator, Virtual Reality

Sylvia is a Professor in Virtual Reality. Working in VR for almost 20 years she developed a unique interdisciplinary research profile with journal and conference publications in both VR technology and social neuroscience. Her work in training and education in VR has been featured multiple times in the media, including *BBC Horizon* and the *New Scientist magazine*.



Pete Woodbridge

Liverpool John Moores University (replaced by Sylvia Pan)

Project Role: Co-Investigator, Immersive Technology

Dr Luo Shan

University of Liverpool (replaced by Sylvia Pan)

Project Role: Co-Investigator, Robotics and Machine Learning

INDUSTRY PARTNERS

LORNA PROBERT

Aardman Animations, Lorna.Probert@aardman.com

Head of Interactive Production

Lorna is responsible for the studio's *Games and Interactive* productions, generating business and overseeing the successful delivery of high quality games, apps and immersive experiences to support the strategies of both *Aardman's* own IP and those of our external clients.



NGAIO HARDING-HILL

Aardman Animations, Ngaio@aardman.com

Head of Attractions & Live Experiences

Ngaio is the Head of *Attractions & Live Experiences* at *Aardman*, responsible for the strategic development and management of a portfolio of global live events, attractions and exhibitions.



CHLOE BARRACLOUGH

Aardman Animations, Chloe.barraclough@aardman.com

Line Producer

Working at *Aardman* for nearly a decade, Chloe is a producer for both the *Interactive* team and the *Aardman Academy*. Chloe has produced a variety of interactive projects across many formats including VR, AR, immersive experiences, web games and digital content for *Aardman's* beloved characters. Chloe also manages the *Aardman Academy's* bespoke training, working globally with industry and educational partners to produce animation related courses and events.



GAVIN STRANGE

Aardman Animations, Gav.Strange@aardman.com

Director

Gavin is a Director and Designer at *Aardman*. Working at the studio for over 14 years, Gavin's creative output ranges from creating title sequences for the *OFFF Festival* and the *Shaun the Sheep Movie*, directing the award-winning stop-motion short *Turtle Journey* for *Greenpeace* and helping *Aardman's* brand redesign in 2021.



JAMES BAILEY

FeedAR, jimi.bailey@gmail.com

Remote Experience Lead

James is a Creative Software Developer and Technical Director for *FeedAR*. He has over 20 years experience developing digital interactive experiences for websites, gallery installations, kiosks and mobile devices. He currently works exclusively with Extended Reality, leading research into new user experiences made available through this exciting technology.



ALASTAIR EILBECK

University of Liverpool, A.Eilbeck@liverpool.ac.uk

Remote Experience

Alastair is an Artist, Creative producer and UX consultant with 20 year's experience working for leading UK digital agencies, as well as founding the highly creative *Meyouandus* studio. He specialises in combining the best of emerging technologies with more traditional film and storytelling media to make compelling, immersive experiences.



CHINA PARTNERS

ZHIXING LIU

Shanghai Theatre Academy

Digital Performance

Zhixing is a Professor and the Dean of the *College of Creative Studies* at *Shanghai Theatre Academy*, the Director of the *Digital Performing Art National Lab (DPA)*, which is one of the key laboratories of the *Ministry of Culture and Tourism* of the *People's Republic of China*. Professor Liu was the planner and director of the documentation-immersion epic drama Yimeng's *Fvour Seasons · The Red Sister*, the spectacular new media visual poem show *Tian Niang*, the new media poetic dance *Paradise Extremes*, the scene exhibition drama *That Year 1978*.



Jingping Zhang

Shanghai Theatre Academy

Digital Performance

Jingping Zhang is a professor at the Digital Art department at Shanghai Theatre Academy and also a member of the Chinese Computer Society. He is mainly engaged in interactive design and the creation of new media art for performing arts, focusing on interactive visual art, artificial intelligence art, expanded reality and virtual production. He has led projects exploring the use of XR with traditional Opera. He most recently led the project "Wormhole Traversal" (Chengdu) digital immersive art exhibition. His work has published in domestic and international core journals.



WEIJA MA

Shanghai Theatre Academy, maweiija_531@126.com

Animation

Weija is a Lecturer of Animation at the *College of Creative Study, Shanghai Theatre Academy*. She's an animation director, her films have won awards in festivals, including the Best Animation short of *Palm Spring*, shortlist of Oscar best animation short. She assistants the audiences tests in the *Shaun Immersive* program.



RESEARCH AND CONSULTANTS

CLARICE HILTON

University of Liverpool, Clarice.Hilton@liverpool.ac.uk

Realtime & Machine Learning Lead

Clarice Hilton is a Research Associate on the *AHRC Shaun the Sheep Project*, where she is responsible for working on developing the virtual environment tests, running experiments and developing machine learning interactions. She is also a doctoral candidate in the Department of Computing at *Goldsmiths University*.



Dr MARINA GUO

University of Liverpool, marinaguo@hotmail.com

Chinese Audience Consultant

Dr. Marina Guo is a cultural entrepreneur, researcher and strategist based in Shanghai and Toronto.. She is the Associate Director of London based BOP Consulting, and serves as the Rotating Chair of China Innovation Service Alliance for Culture & Technology, which is a national initiative (NGO) and industry strategy funded by China Ministry of Science & Technology.



IAIN CANT

University of Liverpool

Visualisation & Sound

Iain has a creative and industrial design background with extensive knowledge and experience in haptic 3D modelling and was responsible for establishing the UK's first haptic modelling centre.

In addition to a background in specialist software evaluation and introductions, Iain has extensive experience in supporting advanced manufacturing SME's to take new product concepts from early stage development through to pre-manufacture prototype.



HAMID KHALILI

University of Liverpool, H.Amouzad-Khalili@liverpool.ac.uk

Dr Hamid Khalili is a Lecturer in Architectural, Interior and Spatial Design at the Liverpool School of Architecture. Hamid's teaching and research lie in the common ground between architecture and digital narrative practices such as cinema, animation, video games, VR and immersive environments. Hamid has taught, developed and coordinated courses across three continents in architecture and film schools. Before his current role at the University of Liverpool, he taught and researched at the University of Melbourne. He has given guest lectures, directed workshops, and has been a visiting critic at several architecture and film schools in Europe, Asia and Australia.





Project Overview

i. Rationale & Wider Research/ Industry Context

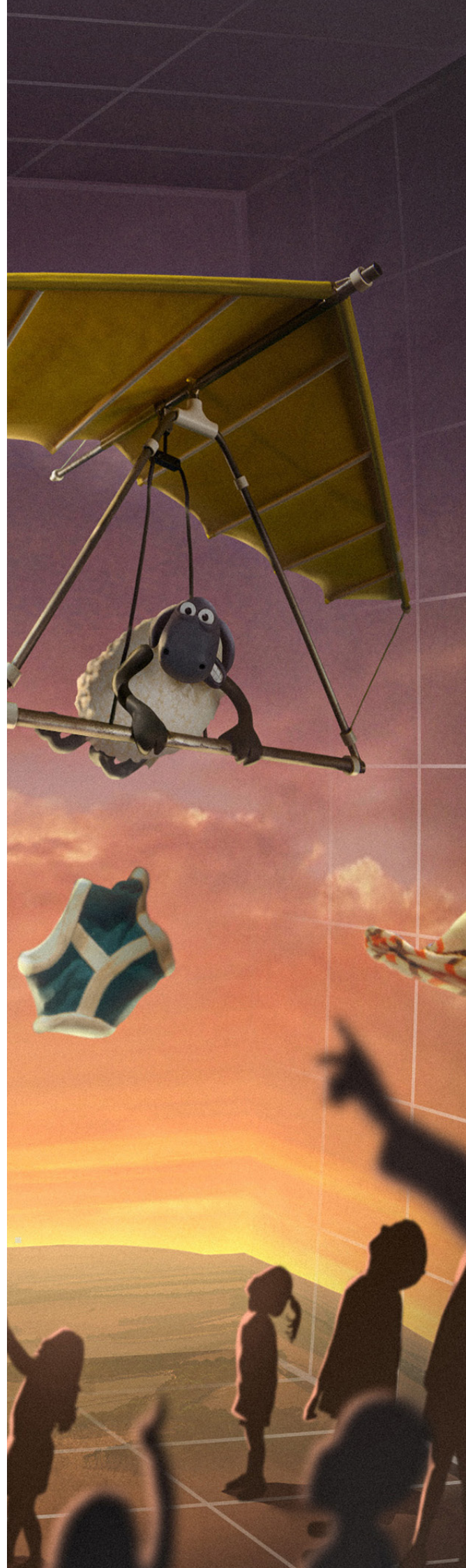
The animation market is increasingly challenged by changes in media consumption and modes of distribution. Innovative concepts are needed that will focus on the realisation of a shared experience for the family entertainment market that turns passive observers of screen-based storytelling into active participants. We, therefore, saw an opportunity arising to create a novel digital/physical spatial experience that embodies the spirit, ethos and participatory nature of games, built around interaction, responsiveness and immersion. With the global games audience estimated between 2.2 and 2.6 billion (UKIE), and a significant number of these in China, we believe that this project could catalyse the development of transformative approaches to engaging animation audiences in novel, and more participatory, experiences in China, but also elsewhere.

The sheer economic potential seems to us to be enormous:

“The overall value of the animation sector in the UK is calculated at £911.9 million” (Animation UK, 2019).

“In 2016, the Global Animation Market was valued at \$138,694 million and is projected to reach \$381,347 million by 2022” (Progressive Markets, 2019)

Despite these positive projections, it is crucial for creators to work responsively and develop content and modes of experience that excite new audiences. One of these areas of large potential growth is in the rise of the location-based entertainment market, set to be \$12Billion by 2023 (Greenlight Insights, 2019),



And the *Family Entertainment Centre/ Urban Entertainment Centre (FEC/UEC)* market set to surpass \$20Billion in 2019 (Allied Market Research, 2018).

For a number of years, revenues for video games have far exceeded many other entertainment media, including film, television and music (Reuters, 2016). Kevin Kelly argues:

[...] this is hugely significant for the future of mediated entertainment, and that 'in the coming 30 years, anything that is not intensely interactive will be considered broken'. (2016)

This has profound implications for the global screen industries and particularly for the physical spaces of entertainment. Understanding and responding to this change in expectations is going to be crucial for a UK animation IP to continue its success in global markets. This is especially important for a young people's entertainment creator such as *Aardman*, who will face an audience that is increasingly accustomed to interactive/ participatory media experiences.

As an opportunity to expand upon our collaboration with *Aardman* (developed through the *UK/China Network Grant*) we wish to push innovation further, allowing us to test our hypothesis that it is possible to create a new form of mixed-reality experience (using games engine technology, sensors, contextual data and AI) and use this to transform a distinctive UK approach to storytelling to a contemporary Chinese context and market.

With access to an already established and recognised IP, we ensure that the investment is directed toward research and innovation rather than audience acquisition. This also means that the project's development can be more innovation-focused as we are not held up by the processes involved in delivering a new creative identity. We want to be the first to develop technology and creative approaches that bring these innovations to the animation industry; and as such, pushing the conventions of the medium into a radically new, experiential domain.

ii. Principle Research Aims & Activities

We set out on this R&D project with ambitious goals. Our aim was to deliver a world-first in research innovation (i.e. technical, methodological, creative application) that would have the potential to transform the delivery of Aardman's high-end animation work (*Shaun the Sheep*) from a currently linear and pre-rendered end-user product (e.g., TV/cinema screen-based) into a non-linear, realtime, responsive, spatially immersive experience; one that can be enjoyed by a wide (family) audience in China (without the need for headsets, gloves or pre-rendered animation), whilst recognising China's cultural context and values in the realisation of this work.

Combining immersive spaces with realtime audio-visual content is of course not entirely unprecedented – predominantly within media art installations – however, our audience-focused, spatially immersive, and responsive approach to storytelling arguably differs substantially from what we might have called in the past **immersive cinema**. Furthermore, due to the application of a quasi-intelligent, realtime system (supported by *Machine Learning/AI*), we were hoping to develop new territories for Aardman and the wider animation sector.

By combining the **scalability** of film/animation with the **intimacy** and responsiveness of immersive experiences, our project was seeking to redefine the term mixed reality (as a family experience with no headsets, no gloves and no mobile phones), providing a scalable concept that could generate significant impact within and beyond the creative industry sector. One might call such a new approach in the film and animation industry a new form of **responsive cinema**.

Our project linked three significant domains of knowledge in the family entertainment market: Animation, Space, Games Technology, which we described would result in a narrative, interactive, spatial experiences. Facilitating this, we had to combine research and creative practice expertise from the fields of animation, architecture, creative media arts, theatrical arts, engineering, AI and robotics as well as gaming. This of course meant that we were facing a fundamentally transdisciplinary challenge; one that would not fit into any normal disciplinary boundaries. We, therefore, assembled a truly multidisciplinary team of academics, industry professionals and creative-technical consultants. Last but not least, we are thankful that we could rely on our collaborating partners at STA in Shanghai to give us valuable input, who deserve a special thanks.

iii. Research Questions & Methodology

We embarked on our journey on a series of research questions from a wider range of fields. Furthermore, much of these “critical unknowns” were practice-based, which required a hands-on approach. To therefore applying a single method was impossible. Instead, we had to develop a tailored, interdisciplinary methodological approach that frequently needed adjustments and revising in response to emerging situations. Broadly speaking, this research looked into the following areas and attached research questions.

- **Target Audience**

Which type of interactive experiences would resonate with audiences (measured/ impact) in our particular cultural context; how can their effectiveness be integrated and quantified (new knowledge created) in an immersive, interactive environment?

- **Story & Conceptional Realisation**

Can the rural setting/characters of Aardman's productions be utilised to create narratives that align with the moral prerogatives of Chinese children's storytelling – particularly given the cultural connections between morality and rural life in China (audience; cultural context)? How can such creative ideas be translated in conceptional, production terms?

- **Dynamic Content Creation**

In the context of our interaction scenarios (WP3 & WP4), what approaches to object-based content creation (e.g., characters; environment; audio; multi-sensory UX) need to be addressed from a workflow perspective in order to make emotionally convincing content assets?

- **Space Integration**

What kind of experiences would be enabled by a location-specific setting (theatrical/ event-based)? How can the experience be built so that it is scalable/adaptable to different spatial contexts (theme parks; entertainment centres; events venues)? What kind of additional costs would need to be considered (scalability; business plan)?

- **Game & Interaction Design**

How do we ensure that our realtime content (WP2) is used (e.g., displayed, projected) effectively for our target audience so that it not only provides a degree of freedom of interaction (gameplay), but also drives an existing story (narrative flow).

- **AI & Sensoring**

How do we involve an AI agent in the storytelling, prediction and reactions to the responses of the audience? How can we create a more interactive and intimate experience; e.g., produce a system in which an AI agent would be expected to identify the common emotional arcs in the content produced by Aardman, predict and capture the reactions of the audience, and change the storyline accordingly?

- **Remote Experience**

The Covid19 situation required us to urgently rethink our “deployment channels” and consider alternative pathways for the delivery of our *Aardman* content. Hence we wondered what kind of approach and concept (creative/technical & economic) would be needed for a “remote experience” in our particular context.

iv. Potential Beneficiaries of R&D Project

- **Architecture & Design (Experience)**

We will produce new insights into the experiential understanding of space/place; progressively important in the field of digital placemaking, where experiences of spaces/places are increasingly mediated by digital tech.

- **Games & Interactive Media Design**

We will produce new insights into the game design and story dynamics of location-based experiences (pervasive gaming) and the ways in which this translates through the application of realtime computer graphics and audio technologies.

- **Multimedia & Digital Communication Technology**

Our findings will inform the technical realisation of an immersive experience; including how we implement data for the control of media content (e.g., light, sound, space and digital imagery), in response to an audience.

- **Human Computer Interaction (HCI) and User Experience (UX)**

We will provide research into the audiences' relationship with the technologies and creative approaches we are using; including how people interact with characters and spatial media environments.

- **Artificial Intelligence (AI) and Machine Learning (ML)**

AI in the context of the creative industries is vastly under explored, particularly given the hugely significant implications it potentially holds. We will create new knowledge concerning the ways in which data and the analytical abilities of ML can generate and manipulate content/storytelling in realtime.





- **Social, Cultural Studies & Audience Studies**

The study fills a conspicuous gap in our understanding of how family entertainment (and the values it presents) differs within the UK and China; aiding research in other creative industry applications.

- **Existing Investment/ Infrastructure**

All our 3 UoL centres/labs are affiliated to the new *Digital Innovation Factory*, a

recent UoL investment; granted £5 million from the *City Region Combined Authority's SIF*; planning to create 400 more jobs in the digital sector. We also benefit from a recent £15 million investment in *Sensor City*, a joint initiative by the *University of Liverpool (UoL)* and *Liverpool John Moores University (LJMU)*, which offers entrepreneurs the technical expertise, business support and international platform needed to collaborate, develop, and promote sensor solutions to a global market.

V. Immersive Experience: A Dialogue Between Space & Narrative

In the broadest possible terms, our project considers conceptualising and designing an **immersive experience**; a term that has become very popular in recent years and which seems to be loosely applied to all kinds of physical, digital or hybrid experiences. The term is naturally often applied to fully immersive VR films, such as the award-winning *Space Explorers: The ISS Experience* (2021), but also projects that are developed for hybrid audio-visual settings, such as those developed by *Teamlab* or *Meow Wolf*; immersive theatrical performances such as those of *Punchdrunk*; or even all kinds of AR mobile phone experiences that might be experienced in public spaces.

“It is important to say that we took inspiration from all of these.”

Having studied such diverse examples, we felt that we needed to not only clarify what the term immersion means in our particular instance, but also to disambiguate the nature of interactive experiences and seek a more nuanced understanding as to what terms such as spatial, narrative immersion or shared experience mean to us.

• Spatial Immersion

An obvious task of our project has been to consider what kind of architectural setting would be needed to create for a crowd audience a sense of spatial immersion; ideally one that they have not been experiencing before. What might seem like a relatively simple task of offering an empty shell, becomes rapidly more complex when considering the safety of audiences, the movement of people, pieces of additional set-design, seating technical set-up for projectors, sound and sensory equipment.

Our starting point for this exploration was, expectedly, a rather familiar setting – the cinema; not only because *Aardman* is known for producing highly acclaimed content for this format, but also because we felt that the cinematic experience as such is widely recognised for providing a high quality, audience-shared, immersive experience.

From this starting point, of course, we digressed considerably and introduced a multi-screen, spatial sound, realtime interactive, cinematic experience and looked for a plethora of opportunities to create an even more increased sense of spatial immersion.

This meant that our thoughts around spatial immersion had to be carefully crafted alongside operational, as well as audience-experiential, point of views.

• Narrative Immersion

This being a project developed for *Aardman* made it clear from the beginning that our starting point had to be the story of *Shaun the Sheep*. With this comes an enormous responsibility to not let the presumed novelty of a multi-screen, audio-visual cinematic experience, any technological gadgetry or clever realtime interaction scenario be in the way for which *Aardman*’s products are best known; that is to provide a beautifully crafted, witty family entertainment fun that is able to transgress age or cultural divides.

We have considered this quality of *Aardman*’s work as an opportunity to think carefully about the power of the story, which we believe can create a powerful sense of narrative immersion.

The term narrative here is understood as ***'multi model and transgeneric instances'*** (Martínez 2014: 111), which we see can occur not only when reading a book, but also when listening to songs, playing video games or indeed going to the cinema when watching a film.

So this is ***'the result of cognitive activity rather than as a quality of verbal texts'*** (Olson 2011: 15), which meant that we had to think carefully how to best allow the audience to get into such a state. In our proposition, therefore, we had to pay attention to the quality of audiences' journey, as they transgress to a series of stages and indeed spaces.

Crucial here, is to recognise the importance of an emphatic response from the audience to everything they are experiencing (space; story; interactions) as an important factor to achieve such a state of narrative immersion.

- **Shared Experience**

During our project, we found that there is more to creating an immersive experience than simply creating an attractive space or compelling story. How these elements are experienced concurrently seems to be key to the overall success. What attracts an audience to a theatre or cinema is arguably not simply the quality of the show or film or a particular actor, but a multitude of social aspects that come with the visiting of such venues or events.

For us it meant that we saw the creation of an immersive experience, not as a single act, but a series of actions that would in the sum create a shared experience. The term shared here is understood from multiple angles.

We sought to offer an experience in an unique ***shared space***; for instance, the immersive theatrical space or what we called auditorium.



The challenge that we faced is that as with any projected cinematic experience, the characters ultimately reside on the screen. We had, however, the ambition to create a sense for the audience that would simulate that they would share the same space (e.g., a barn or field) with our characters. In doing so, we set ourselves up to the impossible task of punching a hole through an infamous audience effect; that of the **fourth wall**, the invisible and imaginary wall that separates any audience from the stage or screen (Brown 2013; Atkinson 2014; Hanich 2017).

We, therefore, experimented and tested audio-visual techniques that were aimed to create the illusion of proximity of characters, objects and architectural settings that would otherwise only reside in our physical world.

But there are also social aspects, such as the notion of a **shared journey**, by which we mean that we thought to create an experience that would have several stages and modes of encounters between audiences and our characters. Our experience would, just like the story itself, have a beginning, middle and end, which translated for our project into developing specific locations (external theatrical and inside the story), with different objectives (of how to best meet audiences' expectations) and bespoke modes of delivery (e.g., linear film; immersive film; interactive installations).

The best example of this, is of course the **immersive auditorium**, which was envisioned as the most immersive stage of the shared journey. The story was developed always with an audience in mind and with the possibility of creating an emphatic crowd response. The team around *Aardman* would be well aware that an immersive theatre would allow us to create a sense of shared moments with others in the same space.





Hence, in relation to for instance interaction scenarios, the team was looking to create story situations in which the audience might need to work together; e.g., to resolve an emerging situation involving Shaun and his friends.

Finally, we have, of course, also considered that it would be important to allow our audience to share their experience with others; particularly those not present at the event. This is a well-trodden path that we would see in other visitor attractions and entertainment parks, such as the taking of selfies that then could be shared with others via platforms such as *Instagram*, *WhatsApp* or *WeChat* in our case.

What was, however, important for us here is the fact that such well-familiar tactics would be embedded into our storyworld.

Furthermore, we looked quite specifically at how China's most important social media platform *WeChat* can be used not only as a marketing or payment tool (see Liu 2018; Xu 2017), but also as a narrative, engaging, shareable web-based connection for our audiences.

In summary, the three pillars on which we built our concept for an immersive experience focussed on **space, narrative** and **shared experience**.

To create a compelling immersive entertainment experience, we believe that all three pillars must stand in a dialogue during every stage of the design and planning process, meaning that they need to be considered concurrently. This often requires an act of co-creation in a non-linear process, which poses its own set of challenges and makes good communication between teams and team members imperative.

I. Target Audience

Aardman is known for providing high quality family entertainment to a diverse and intergenerational family audience and our proposed immersive experience would follow this format. Having this said, this being an experience that was developed for an audience in Shanghai, we had to take into account variables such as cultural differences and values, which are reflected in the fact that Aardman created a bespoke story for this prototype experience. The input of our partners at the Shanghai Theatre Academy were very important here. Furthermore, since our project

focused on a location-based experience, and not one that can be consumed by an audience of all ages at home, we had to consider a series of particular issues and consequences. For instance, our audience would probably come in small groups, since children would need to be accompanied by one or more adults. We, therefore, had to consider the implications for the entire audience journey, but in particular the impact on the auditorium design, such as seating arrangements, mobility radius and more, which are reflected in our concepts below.

A Chinese Audience

Developing the story through the lens of its audience was key for Shaun Immersive, meaning that we set out to define who they are, their needs and motivations. In consultation with our Chinese partners at the Shanghai Theatre Academy (STA) and CAVA, we noted that while some of the audience would be familiar with the Shaun the Sheep brand, others might not necessarily be familiar with it or have perhaps only a visual awareness.

We defined our core family audience for this Shanghai-based experience as follows: kids (6-12); young professional adults; girls 16-24; young couples; urban communities; parents and grandparents with their one child; affluent; living in tier 1 cities. In light of our envisioned audience, we drafted the story with the following considerations in mind; again in consultation with our Chinese partners:

Morals

The story should have elements showing a particular connection with rural life and a duty of family/friends to help one another.

Desire for a Shared Experience

The story should support our aim of creating a shared/quality family experience; give kids a quality experience.

Education

The story should have some kind of educational element, specifically considering the Chinese context.

Character Connection

Since not all audiences might know the brand, the story should provide an opportunity for building up an all important character connection.



Fig.1: Chinese audience development



Fig.2: Chinese audience testing session

With the above in mind, we explored several routes for the story that aimed to have cultural resonance with a Chinese market. For example, we explored a zodiac animal route for a new character set, where

Shaun meets a **mystical dragon**. This was a first for Aardman in allowing that fantasy world to combine with the world of *Shaun the Sheep*.

Whilst typical Shaun stories have a positive outcome or end in a resolve, they aren't intrinsically moralistic.

With our audience in mind, we explored ways to bring moral into the narrative in a way that felt natural to a typical Shaun

story; the new characters having positive qualities that helped the flock on their way, bringing in educational messages of support and kindness in strangers whilst also aligning with a typical Shaun story trait of characters all having their own personality traits that move the narrative forward.

Not to rest on our assumptions alone, we rigorously tested the story with a Chinese audience to gather qualitative feedback that fed into each draft of the story. This exercise was invaluable and helped us understand our audience better and tailor the story to suit.



II. Story Development

i. From Linear to Realtime Interactive

Shaun Immersive is a unique audience experience concept that builds on the idea that a *Shaun the Sheep* story, traditionally told in linear format would be shown as realtime interactive experience. We were naturally wondering what this change of the way in which the audience would experience *Shaun the Sheep* would have implications on the story development itself.

Aardman content always starts with character and story, not least *Shaun the*

Sheep episodes and features, so this was intrinsic to carry through to our story development for *Shaun Immersive*.

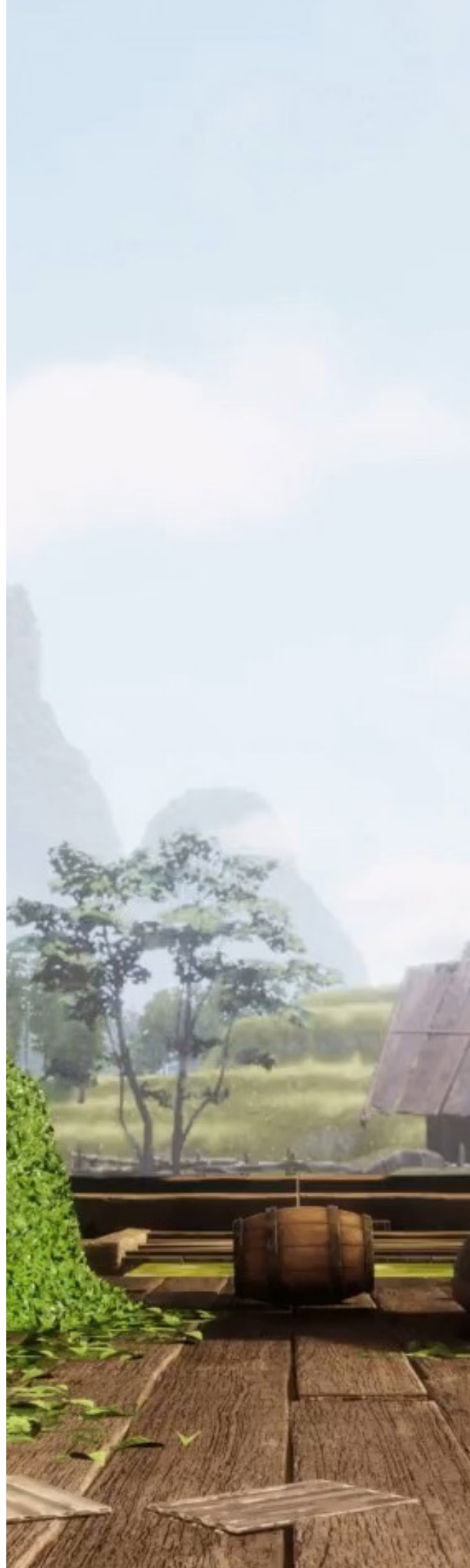
We aimed to follow a normal episode length of around 11 minutes with a defined beginning, middle and end. Certain traits like, the **comedic conceit** is always at the core of each story and **finding the funny**, a guiding principle in creating each story/episode. *Shaun the Sheep* episodes tend to follow convention, which we kept in mind for *Shaun Immersive*.



Some of these are:

- **An inciting incident which sparks a self-contained narrative within the episode, usually involving multiple characters.**
- **Each episode is stand alone and the Flock and the Farmyard resets after every adventure.**
- **Comical slapstick moments, with the story often playing out through very physical set-pieces.**
- **Characters are key, each has their own distinct way of solving problems. The show has an established dynamic between all the main characters.**
- **No dialogue, therefore everything is communicated through gestures, performances and animal sounds to infer dialogue.**

We concluded that it would be important that *Shaun Immersive* would hold on to such a story framework, allowing us to build on a successful format and, at the same time, to be more experimental in other parts, such as the look of the final immersive film experience.



ii. Branching Narratives

Unlike traditional linear Aardman stories, the Shaun Immersive story needed to be interactive; one that might change each time could be displayed and enjoyed in a 360 degrees immersive space and with potentially different routes and endings. Since our story would be delivered with a games engine, we could consider a series of different options.

There were complexities around the idea of using multiple-branched narratives. While our aim was to give the audience a sense of agency, decision-making powers, and different experiences, we also recognised that managing branching narratives would involve significant risks and possibly too large of a task for the scope of the project and its requirements.

We were faced with the complexity of resolving a story in a set amount of time of course. While Aardman is used to such pressures within linear 16x9 constraints of a TV screen, it is a much different challenge within, for instance, 15x15 metres volumetric space with multiple walls and screens. This complexity is amplified by the fact the audience controls the gaze, which is a challenge that Aardman normally does not face in linear content delivery, which is controlled by where the camera is pointing.

Through simulating the build in VR, we were able to make some assumptions on where the audience might position themselves, giving us 'hot' spots and having a better understanding of perspective from differing positions around the space.

The feedback from the VR simulation fed into the story development as we needed to understand a little better what the audience should be looking at so the story makes sense and, most importantly, so the comedy lands and is entertaining.





iii. Specific Challenges

There are still areas we would like to explore further and understand better to improve the overall story experience. Indeed, while VR has been a helpful tool, such a setup also had its limitations and further on location tests, such as in an XR studio, would certainly help our development in the future.

We found that the following points summarises some of the challenges we faced during the core project tests:

- **Scale of Characters**

Telling a Shaun story in larger space, requires a lot of considerations regarding the layout and framing so that the characters could be visually registered from a distance.

- **Frame Rate Perception**

Shaun the Sheep, traditionally, is animated on 12 frames-per-second in stop-frame animation. We were working at 60 frames-per-second in the realtime engine *Unreal*. That changed our approach quite

dramatically and was a key driver in us wanting to understand how to translate *Shaun the Sheep* from one technological medium to the next. What can be kept, what should be changed, and would such a change have an impact on experiencing the story?

- **Storytelling Stance**

Shaun is usually a linear character who operates within his world and his story. His world is normally divided from the audience by a screen (the fourth wall). With this project, however, we had the chance for Shaun and the flock to be able to acknowledge the audience and bring them into the story to perform with the flock.

iv. Technical or Creative - which comes first?

Whilst content production is often a quite well-rehearsed process for *Aardman*, developing interactive content was certainly a new challenge for *Aardman's* creative story, and to some extent the CG teams. In linear storytelling at *Aardman*, the story and creative development and the story are locked before the technical pipeline kicks off. This modus operandi, however, did not work for such an immersive, interactive project. This meant that it certainly disrupted some of *Aardman's* more traditional production pipelines, leading also to some friction between creative and technical processes; each of these presenting of course its own set of limitations. Here to mention is, for instance, the question as to if one should design the story around the technological potential or build the technology around the story/creative?

It ended up being a bit of a dance between the two, meaning that we did a series of tests and iterations to refine both, developed in parallel. The following is what we learned and what we would like to adapt to in future phases:

- **Quicker Prototyping**

We would aim to be able to make quicker toys and prototypes, allowing us to test ideas quickly and inform both the technical and the creative teams earlier in the production.

- **More Technical Artists:**

We would want to prioritise more time and resources for the Technical Artists, who we see as the ideal people to have making early tests, prototypes and experiments. We would envision them to have an eye on what is technically possible, but also on making it as creatively exciting and intriguing as possible.

- **Design Iteration**

This project has shown that design iteration is key, by which we mean that it is important trying something out, testing it out, then making adjustments. We did not get the chance to physically visit our testing space (due to Covid restrictions), meaning that we had to resort to virtual reality for such iterations. While it was not quite the same, we found it to be a good proxy.





III. Dynamic Content Creation

Aardman is an Academy Award® winning animation studio which enjoys global success as creators of, for instance, *Wallace & Gromit*, *Chicken Run*, *Morph* and of course *Shaun the Sheep*.

i. Context

How is this content being created? While *Aardman*, which celebrated its 50th anniversary in 2022, has begun to diversify its content creation and is increasingly involved in using advanced digital methods, the majority of its portfolio is produced in bespoke, physical studios using a process called *stop-motion-animation*; a time incentive creative art.

This, of course, is a linear process that involves the creation of miniature, plasticine characters and physical, miniature sets, which are subsequently carefully placed, lit and photographed – one small movement at the time – before later being assembled frame by frame using bespoke, digital tools.

The commonality, therefore, between these diverse outputs is the linear way in which content is created, using precisely this traditional stop motion animation technique, which *Aardman* arguably not only perfected, in terms of quality of the creative outputs, but also provides a recognisable trademark of its operation.

This context is important to understand the gravity and impact of the decisions we took that changed this “process” and “method”, which this project proposed and tested. Our team embarked on a journey for a new kind of content creation which, as a consequence, also opened the doors for a new kind of content delivery.

Aardman is used to producing some of its content with sophisticated digital modelling tools. What was different in our case, however, was the decision to import and further manipulate such content using a game engine, allowing us to play content in realtime and make it interactive.

The team initially decided to use *Unreal Engine 4*, later upgraded to *Unreal Engine 5*, which arguably combines a state-of-the-art rendering pipeline capable of delivering realtime graphics on a par with pre-rendered cinematics, as well as a relatively mature spectrum of animations tools, which can aid in transitioning creative teams to this new process of delivering animated content.

We found that its code base is also relatively flexible with methods of node based content creation. These are relatively intuitive and lend themselves to fast prototyping, potentially ideal for storyboarding of rough sequences whilst still allowing a creative team access to C++ based lower level tools; e.g., for the creation of custom assets.



ii. Realtime Workflow

Unreal Engine makes use of rigged 3D characters and 3D assets in a way which is essentially the same as if those assets were to be used in pre rendered animation pipelines. We found that this actually means that animation studios do not necessarily need to radically reorganise their working habits in order to take advantage of a realtime rendering process. Realtime animations, enabled by rendering tools such as *Unreal Engine*, could remove the lengthy and therefore costly process of waiting for rendered cinematic output to be exported. This process is known to often incur additional costs, for instance, smaller studios, who might need to rely on the services of external render farms.

We found that there is another potential advantage in using realtime engines over more traditional pre-rendered or studio techniques.

A games engine essentially provides a virtual studio set up; divided up into scenes. This means that changes to individual assets or shots can be done far more easily and quickly than in a physical environment.

While in a physical studio setting it might be time consuming or disruptive to re-shoot a scene (where each step is part of a linear, pre-rendered and consequential workflow process), scenes inside a virtual studio are easy to manipulate.

Different kinds of virtual lighting, camera angles, or even multiple-camera set-ups can be used within a single scene without increasing the rendering time that each camera would normally require.

Producing content, such as characters or settings, directly inside a games engine comes of course also with some potential caveats. The learning curve is relatively steep. Indeed, some animation studios which want to create a particular look and want to have a high degree of control in their asset creation, might choose to continue to produce pre-rendered, animated assets as they have done before.

In such a case, a games engine could be used to simply arrange animated scenes at the final stage. In reality, however, as with any major change to a studio workflow, personnel must be trained to use a new toolset. Furthermore, output assets might need modifications to materials to suit a new type of rendering engine and assets which previously looked fine from fixed angles, might need adjustment to reach an acceptable look from multiple, dynamic camera angles. This is particularly relevant for projects which utilise immersive scenarios; potentially with dynamic unpredictable audience interaction points. Animation studios may have to incorporate fundamental changes to their design methodology and transition away from linear story lines towards more modular representational and narrative approaches.



IV. Spatial Setting

The design and layout of the space in which *Shaun the Sheep: Immersive* takes place is integral to the success of the experience. As a result, significant consideration was made to its configuration.

i. COVID-19 Pandemic: Impact on Developing/ Testing a Location-based Experience

We started our project a few months prior to COVID-19 restrictions and travel bans being imposed by governments around the world. Our original intention was to spend a significant time in Shanghai and with our *STA* colleagues to jointly develop with them a physical simulator of our location-based experience in a new *XR lab* that was intended to be built on the new campus.

Whilst this plan was still underway, we began to work with *Aardman* on the storyline, who also began modifying several 3D-rigged character models and additional assets. These assets were used for tests inside *Unreal Engine* and evaluated as suitable for further immediate usage tests as part of our proposed realtime engine workflow.

In terms of the location-based experience, we agreed on the assumption that our prototype experience would fit the dimensions of the new *XR lab* at *STA* which, after some consultations and input in terms of specifications from our end, we agreed on marking up an area at the Shanghai *STA* facilities of 15x15 metres and 5 metres high. This was an important milestone in the sense that we now were able to work with precise architectural drawings for our auditorium, which could now be translated into our realtime environment.

This positive development was brought to a halt in March 2020 with COVID-19 restrictions severely impacting our project. While the development of such a challenging location-based experience would require of course a close collaboration between geographically and culturally diverse teams, the Covid pandemic required us to swiftly re-evaluate our situation and come to a decision in terms of how to best simulate and test the spatial setting of our proposed immersive experience.

Constantly changing COVID-19 restrictions on both sides of our international team caused uncertainty around the delivery of an *XR lab* environment by *STA*. Furthermore, it made it difficult to estimate when our planned visits to China and vice versa could occur.

ii. 3D Reconstruction & VR simulation of XR Lab Space/Auditorium

This led to two major changes to our original plan. Firstly, we realised that putting all eggs in one basket might not provide the kind of resilience that was needed for this and similar types of projects in the future. We, therefore, with the support of the AHRC, added a further work package that would focus on a **remote experience**, using mobile phone technology in a Chinese context and market.

Secondly, and this is more relevant in terms of producing the design for an auditorium space in this section here, we decided to work in a virtual reality (VR) environment. This meant that first and foremost, we needed to produce a 3D reconstruction of the proposed XR lab space to be developed in VR, in order to aid us in the decision-making of the design and layout of the auditorium space.

We came to the conclusion that this course of action would provide valuable and much-needed insight for the animation teams as to how their work would be displayed in the XR lab testing space. To facilitate this, the team at CAVA adapted a 3D model supplied by STA to form the basis of a robust VR exploration space, which could display animated cinematics on the four walls (and later the floor) of the proposed immersive environment. It also provided a very useful architectural testbed for furniture and layout options, as well as display equipment required in the space (See Fig. 4, 5, 6)

Fig.3: View of 3D Model converted from architectural plans of ST XR lab





Fig.4: View of 3D model Unreal Engine VR, testing our application

Fig.5: Projector Locations for XR lab space in VR Testing Application

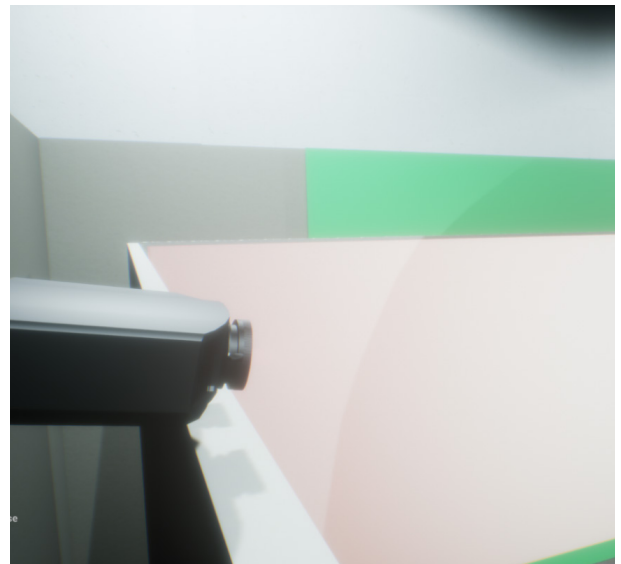


Fig.6: Moving Image Test: Simulated projectors in XR lab space in VR Testing Application

In a further developmental step to produce a VR simulation that would allow us to, for instance, design layout opinions and audiences, in the auditorium space, it was necessary to make some decisions in terms of how we would simulate the display of moving images on the VR walls.

We iterated our desktop application in such a way that it could display a video file across our four “projection walls” in the immersive XR lab/auditorium environment. To deliver this, our desktop XR lab test application would include realistic projectors that created a colour projection using simulated red, green and blue lights (RGB). This kind of light setup inside *Unreal Engine* enabled us with the help of virtual projectors to predict the feasibility of real projectors in such a dimensioned space of the XR lab/auditorium and where

exactly they would need to be placed. This formed a strong basis for building a tool which could simulate the changes to the immersive space that would be required if it were moved between real world venues of different spatial dimensions.

In the last step, we imported various short films and “mood reel” produced by Aardman, aimed to give a sense of the tone and animation style one might wish to convey in our final experience (See *Fig. 4,5*). In doing so, we found a working way to mitigate the then present circumstances and build a successful VR platform capable of playing directly projected moving images onto virtual surfaces, providing us with a good basis to start our spatial design for the auditorium and other further developments.

Fig.7: Moving Image Test: Simulated projectors in XR lab space in VR Testing Application'



iii. Immersive Theatre Layout: Seating & Spatiality Development

For a number of practical reasons, we decided on a square auditorium with a length of 15m to either side, enclosed by a screen wall with a height of 5m. To ensure a safe and reasonably quick on-boarding and off-boarding of the theatrical experience, we placed two generous openings into the box serving as an entrance and an exit, placed on different sides so that people flow in one direction only. From this basic layout, we developed a series of alternative layout options exploring ways in which an audience could experience a story in such an immersive environment.

We were working from the assumption, which we later tested, that the centre of the theatre would allow the best viewing experience. Our first layout assumed also that, similar to a cinematic experience, the audience would see the show from a seated position. Due to the immersive nature of the show, this required us to consider special chairs that would freely swivel 360 degrees. This basic seating arrangement shown here, which is neglecting for a moment that people need to get to their seats in comfort, would offer a seated

experience for approximately space for 37 people.

We developed variations for the layout of the rotating chairs, some of which are more spread out as seen here, while offering good audience numbers (high 50s and low 60s). While the generous spacing would provide a degree of comfort, such design tactics also showed limitations in the viewing experience. Spaces closest to the centre, for instance, have good viewing capability. Seating located furthest from the centre, however, would potentially suffer from visual distortion and general discomfort from being too close to the screen.

In response to that, we developed slightly more dense models where the provided seating offered a compromise between surrounding space and more centre position. At the same time, we valued the creation of smaller empty pockets inside the circle, providing potentially a better viewing experience and generally increased levels of comfort.

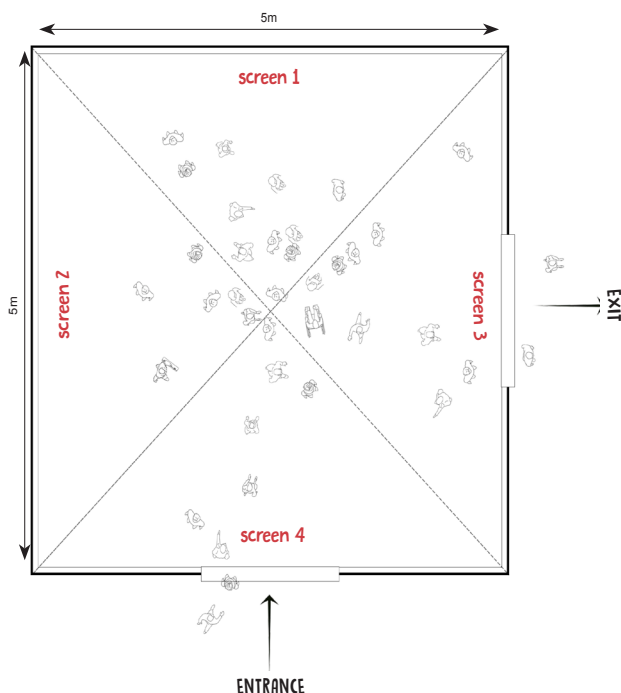


Fig.9: Principle Screen layout of 5m square with entrance and exit

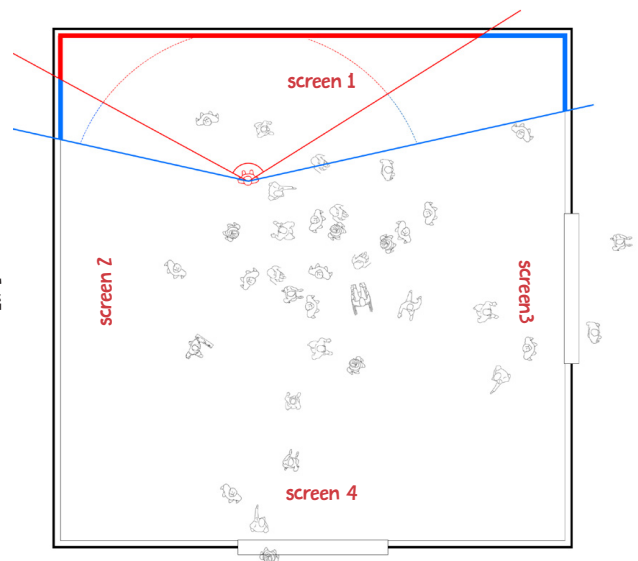
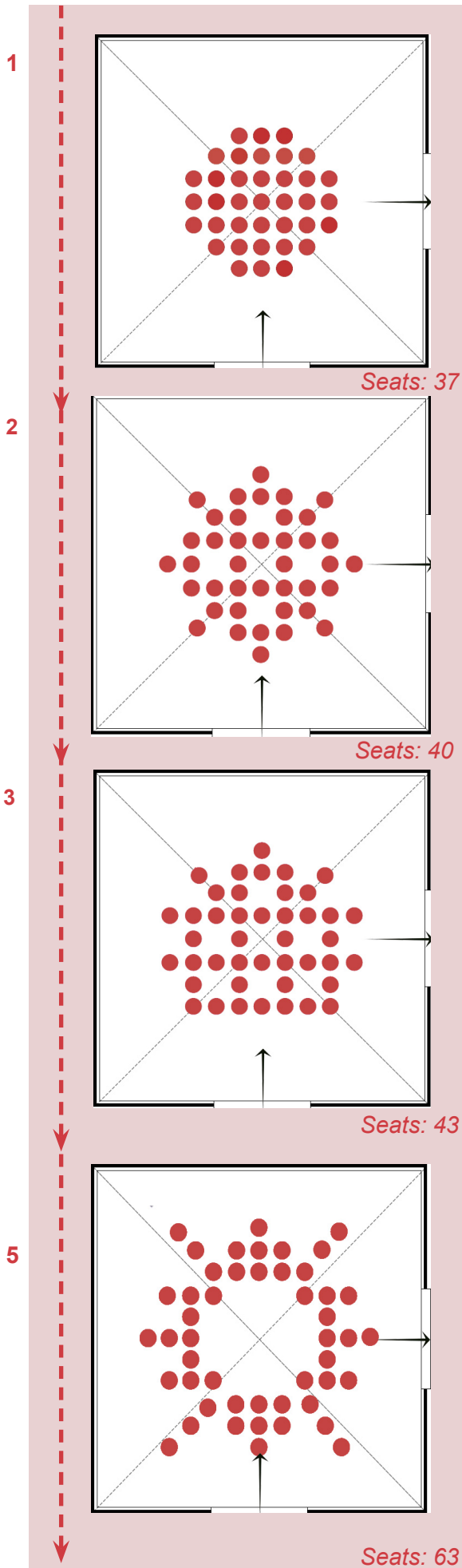


Fig.8: We can watch max 160 D (120 D binocular vision + 2 * 20 degrees on both sides). So, in the most ideal situation, at a specific moment in time, max 3 screens can contain significant actions.



Standard Seating

A standard seating arrangement within this space initially consists of approximately 37 seats.

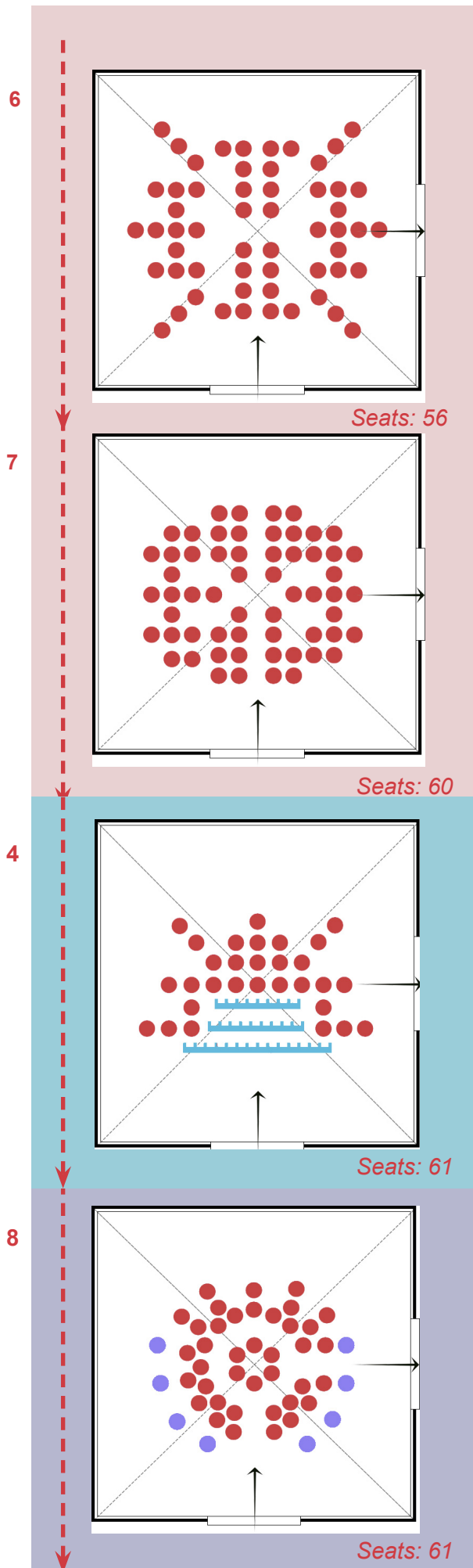
360 ° fixed Seating

Seats that have the ability to rotate 360° prevent the audience from being limited to one or two screens. Being able to swivel within a fixed position also adds an element of movement and interactivity to the experience.

The investigation into the seating arrangement revealed the need for gaps within the rows of chairs. This is to allow for greater accessibility, and for the potential use of the floor space as projection areas.

Variations within the layout of the rotating chairs were developed.

The experience of the individual visitor is considered from each chair position - spaces closest to the centre have the optimum viewing capability. Seating located furthest from the centre suffers distortion.



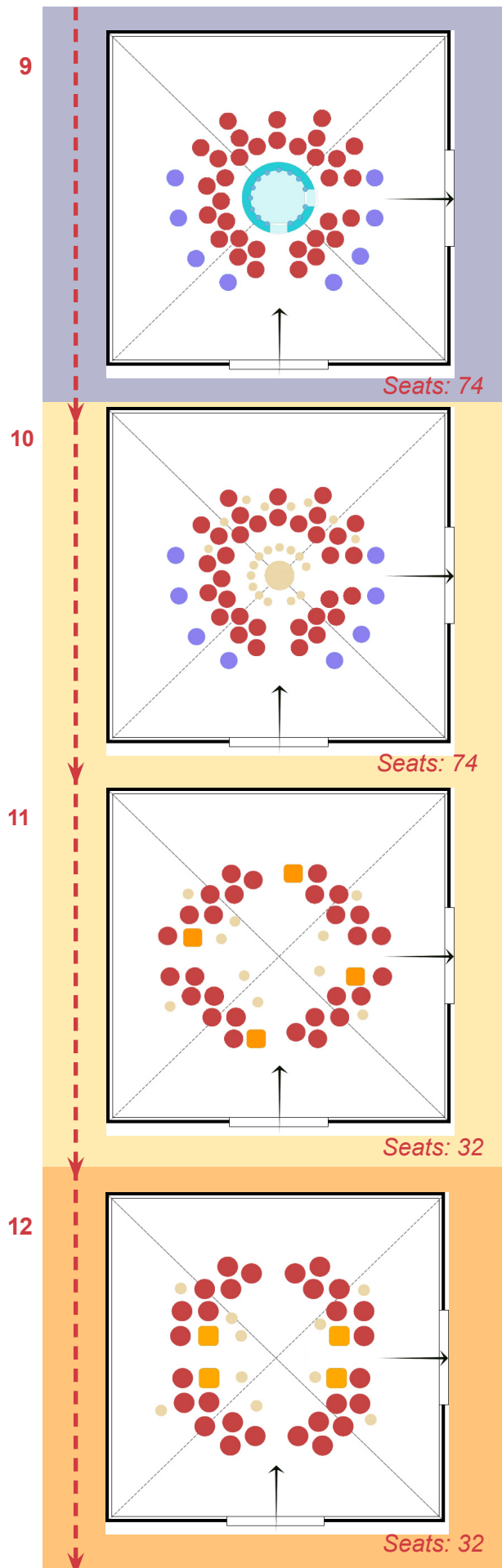
Efforts were made to reduce optical distortions by ensuring the majority of the seating was as close to the centre of the space as possible.

Standing Seating

In order to allow a greater number of people within the audience at one time, standing seating mixed with regular seating was considered. Though this greatly improved the number of people within the space, it created a division within the type and quality of seating.

Bistro Seating

In order to increase visitor numbers in the theatre, we also tested the idea to have a mixture between seated and standing audience. We envisioned that seated adults and children would sit in the centre on rotating chairs, surrounded by bistro-style tables where adults could stand.



This idea progressed into developing a special zone in the centre that would be dedicated to children, which significantly increased the maximum number of people in the space, while retaining a good field of view for most people in the theatre.

Children's Seating

A further consideration was given to movable seats for children, i.e. lightweight furniture that children could move and position wherever they want. These would be placed around the fixed seats in the theatre. Next to this offering a degree of freedom and flexibility for the audience, it also offered increased visitor numbers.

The same concept of a mixture of fixed (rotatable) and movable seats was tested against a series of different layouts. This example here shows how the centre space could be clear of seats, giving us the opportunity to introduce floor projections. On the downside, however, this reduced visitor numbers in the space.

Accessible Seating

A further consideration was given to accessible seating, such as for visitors in wheelchairs. Designated areas were introduced near entrance and exit zones, while retaining good visibility of the screens.

iv. Layout: Findings

These layout design exercises brought to light a series of interesting findings. Immersive theatrical experiences are a complex system with many variables to play with; all of which require a lot of thought. As soon as we left the traditional cinematic layout – with one big screen in front of a seated, stationery, single-view-orientated audience – we found that compromises were necessary to achieve feasible overall results. Some of the fundamental questions we asked and which we had to weigh against each other included:

Operational questions – such as the speed with which an audience can safely enter and exit the theatre;

Sense of immersion – an audience would experience, considering for instance their different positions in the theatrical space;

Economic questions – considering for instance how many people could take part in the paid show during one time. The design variables we tested against these questions included:

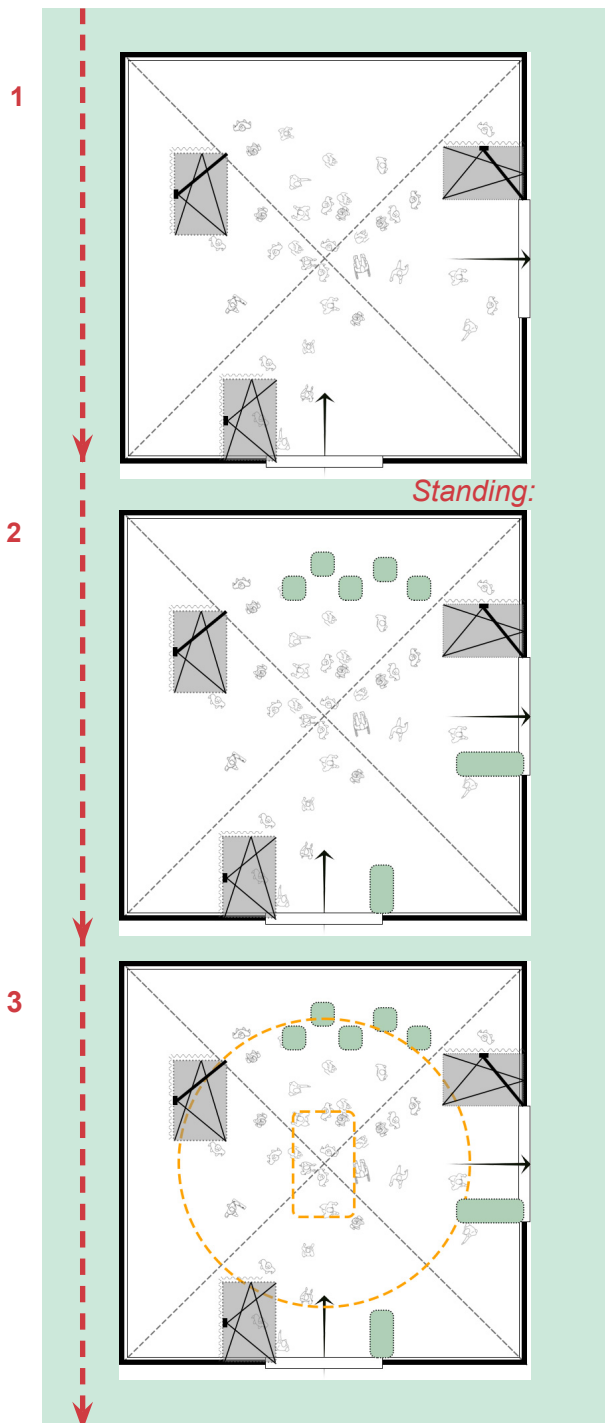
- geometric clusters that would place the viewers in different positions and variable distances to the screens;
- a mixture of a seated and standing audience;
- special zoning, such as for children or people with special needs;
- special seating, such as swivel chairs that would allow an active 360-degree viewing experience or bespoke seating for kids.

The design research on these topics raised many critical questions and led to fruitful discussions within our team and external stakeholders; e.g., such as designers of visitor attractions. After careful consideration, we decided to also explore yet an altogether different audience concept for our immersive Shaun the Sheep theatre – ***that of having a free-roaming audience in the auditorium, giving them a maximum freedom of standing, moving or finding a seat to see the experience.***



v. Free Roaming Investigation

Explanation of transition from seating to free roaming. Insight into potential benefits and complications.

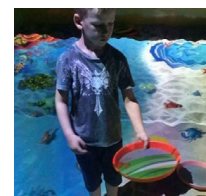
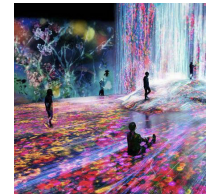


Dynamic Elements

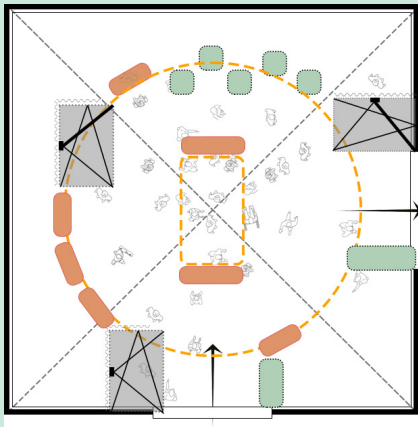
DE 1: dynamic content, projected on side walls, for an audience to touch > response (e.g., a glass char with rice falls off a shelf and shatters). audience engagement does not create a story dependency.

DE 2: dynamic content, projected on the top surface, for an audience to touch > response (e.g., in tea leaves which move and emit a sound when moving a hand through). This is about **discovery**, fun, sense of being inside a dynamic story world. This element feels incidental and offers a contextual experience.

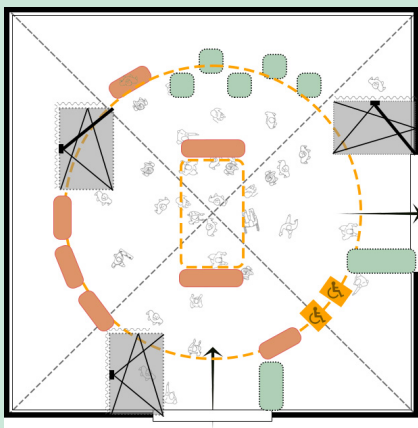
DE 3: dynamic content zone, projected on low frequency (rumble) floor for an audience to stand on and take action > response. A certain number is needed and/or rhythmic jumping. This is about **interaction**, fun, sense of being an actor in a dynamic story world.



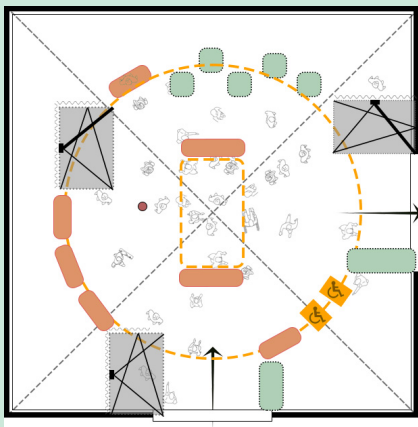
4



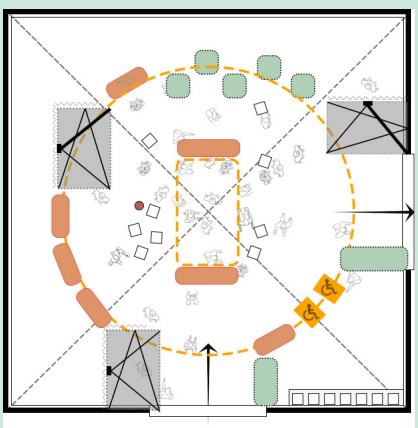
5



6



7



Physical Set Works

PSW 1:

Solid objects on which people can sit on; circa 50cm high; for casual seating of those who do not want to stand/roam (e.g., a wooden box with softer seating cover)



PSW 2:

Assigned accessible seating areas for those who utilise wheelchairs.

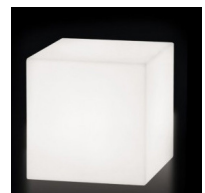
PSW 3:

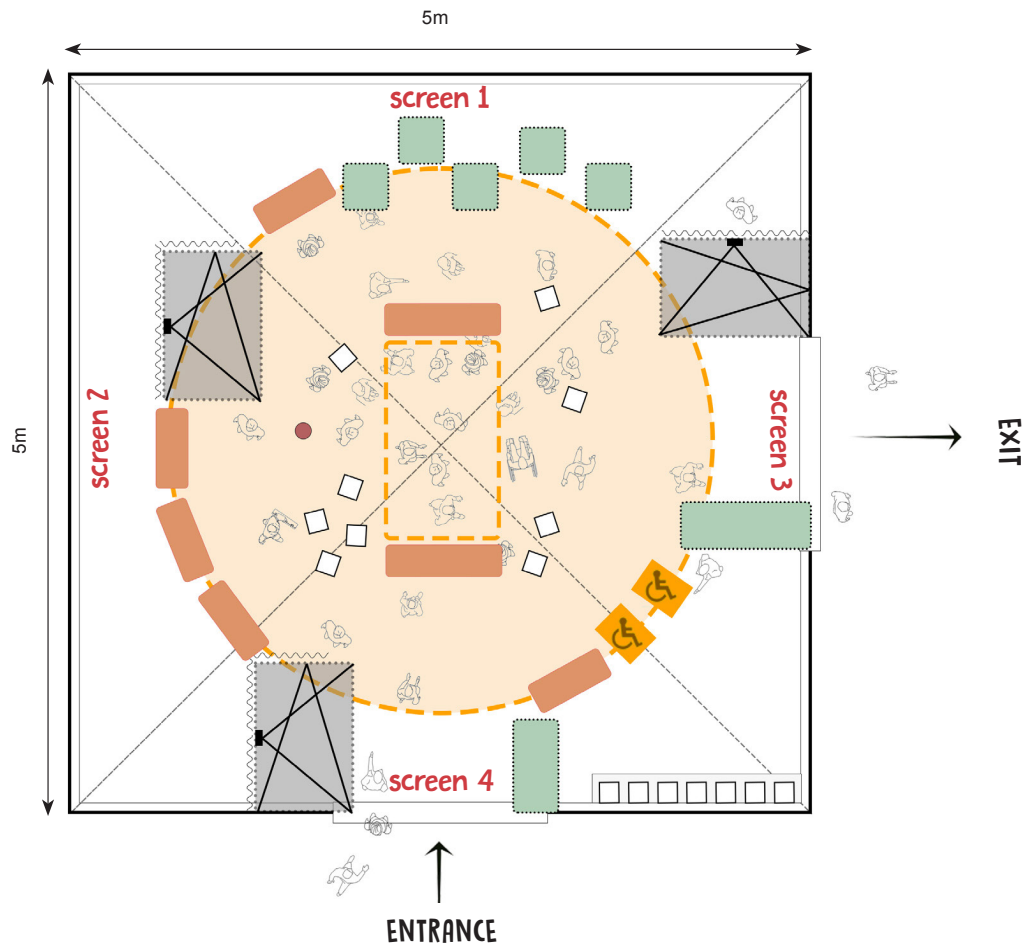
Moving responsive mouse / top projected; to create fun and amusement; to be discovered by kids; not central to the flow of the story.



PSW 4:

Translucent objects (e.g. small seats) / inside lit; circa 50cm high; to match the atmosphere (translucent white box changes to red at the moment when the alarm goes on in cargo space and the hatch is opening). Illuminated seats can be placed in a conductive pad to be charged overnight.





1. translucent objects (e.g., small seats) / inside lit; circa 50cm high; to match the atmosphere (translucent white box changes to red at the moment when alarm goes on in cargo space and the hatch is opening). **FUNCTION > FLEXIBLE SEATING**



2. solid objects on which people can sit on; circa 50cm high; for casual seating of those who do not want to stand/roam (e.g., a wooden box with softer seating cover) **FUNCTION > FIXED SEATING**



3. solid objects, inside projection; circa 150cm high; to match the narrative space (solid white/black box change from being a suitcase to a hey-stack to wooden box etc.) **FUNCTION > DISCOVERY / ATMOSPHERE / RESPONSIVE SETTING**



4. solid objects / top projection; circa 100cm high to create a dynamic effect that fits to respective environments e.g., Tea leaves, tea smells coming from them when touched? **FUNCTION > DISCOVERY / ATMOSPHERE / RESPONSIVE SETTING**



5. moving responsive mouse / top projected; to create fun and amusement; to be discovered by kids; not central to the flow of the story. **FUNCTION > DISCOVERY / ATMOSPHERE / RESPONSIVE SETTING**



6. activity zone / top projected / rumble floor; central area (best view), where (group) participation is required; central to the flow of the story, activated by e.g., low frequency. **FUNCTION > INTERACTION / STORY-DRIVEN, RESPONSIVE**



7. charging station; illuminated seats can be placed in conductive pad to be charged over night **FUNCTION > THEATRE, OPERATIONAL**

FUNCTION



V. Game and Interaction Design

i. Collecting Human Data

We are mindful of the fact that projects such as our, which proposes to use sensors to collect human data, for instance, in relation to an audience's location, movement, crowd size or emotional responses (e.g., facial recognition), will require strict considerations around ethics and respect of the laws of the country for which the experience is being developed. With our project, we would like to highlight the importance of developing a transparent and ethical approach to data collection. Such an approach should consider also, but not exclusively, the following points:

- **Informing the audience about data collection (why; how)**
- **Seeking acknowledgement and permission prior to the show**
- **Avoiding unnecessary collection of data**
- **Anonymising data collection (and storage, if necessary)**
- **Avoiding storing any data wherever possible**

Our proposed immersive experience has focussed on sensory data that would be strictly anonymised, not stored and only be used to story-trigger events in realtime. Having this said, we would urge any operator of an immersive experience such as the one proposed here to have a robust policy in place to deal with human data, in order to mitigate their risks and that of their visitors. In the case of our research project, we went through a university ethics approval process before, for instance, pursuing any test with audiences.



Fig.10: Team workshop at Aardman Studios, Bristol

ii. The challenges of designing interactions with an unpredictable audience

We believe that a sense of immersion does not only come from a physical experience of being inside a space that has an audio-visual projection setup, but also from being immersed in a storyline. In fact, we could go beyond that and say that the connection to the story or sense of being immersed in a shared story world (a sense of co-presence with animated characters and the audience) comes from the audience's sense that it can act and interact in this fictional, narrative environment. This has

the consequence that our and similar types of immersive experiences will find a need to incorporate ways to interact with the audience. This would need to be done with a series of well-planned (predicted), bespoke designed (tailored) and seemingly fluid interaction (timed) scenarios, played out inside a spatially very limited environment that is filled with its own set of audio-visual problems and is filled with an inherently unpredictable a diverse audience. Needless to say that this is easier said than done.

iii. Interaction Framework

Our project considered a wide range of sensor technologies, powered by an AI system or a Machine Learning algorithm. The reason for this was two-fold. Firstly, we wanted to get a better understanding of the audience, such as their behaviour, their mood, their interactions with other audiences, onscreen content or other aspects of the environment. Secondly, we believed that this better understanding would ultimately allow us to offer a more tailored and more immersive experience, the sense of playing an active part in the story.

As part of our research, we developed a user-centred **Interaction Framework**, which could be applied to our, but also seems applicable to other, similar types of immersive experiences. Placing the user in the centre of the experience seemed essential to us, however, at the beginning of our journey, it was unclear as to what this meant for our project. Our work confirmed our hypothesis that the audience's relationship to the "experience" is in an immersive environment

fundamentally different to, for instance, a cinematic experience or even gaming. Our immersive project shared properties with both instances, but, was also distinctly different. It shared with cinema a sense of being in a place with others, enjoying a shared audio-visual, narrative experience. Yet, the cinema, of course, does not invite the audience to be fully surrounded by a story, nor to interact with its characters. Gaming, on the other hand, shares with our experience the notion of agency; a shift from cinematic observer to agent; a sense of taking part in the story world or even being able to influence its narrative outcome.

Yet, for the most part, gaming is a spatially isolated act that rarely happens in the same space with potentially dozens of other people; all being immersed and sharing the same moving image-space. So how could such an interaction framework for immersive experiences look like? We decided to divide our framework in two types of audience interactions – covert and overt.

iv. Covert Audience Interactions

For the categorising of such interactions, we again placed the user/audience in the centre. The first form of such an exchange between show and audience we termed **Covert Audience Interactions (CAI)**, by which we mean that the audience would not need to be unaware to get the benefits from such an exchange of data or information. This information might not necessarily inform the immersive theatrical show, but give valuable information to the operators of the overall experience. Here to mention is, for instance, that optical or other sensors could give information on the length of a queue at entrances or exits. A lot of academic work has been produced on the psychology of waiting lines (Maister, D.H., 1984; Furnham, et.al., 2020; Adrian, J., et. al., 2020) that addresses issues such as the social psychology behind the formation of bottlenecks). Anonymised crowd data that can be collected with such a covert system can feed back to operators and trigger actions that could have an immediate and direct impact on improving the queue line experience and preparing them to enter a storyworld.

In terms of the immersive show, a covert system can provide operators with a better understanding of audiences' behaviour within the theatrical space. It can give, for instance, quantitative information on numbers in an auditorium, their position in a space, the time needed to go from one area to the other; their level of interaction in relation to other elements of the show (screen, space, other audience members), or even their mood.

A particularly interesting problem here is the cross-referencing of sensor data. To give a simple example, an optical sensor reading **1) number of audiences, combined with a sensor measuring 2) audio level** could provide information on their level of engagement or attention to a particular show. Comparing such data of different shows could provide clues on the type of programme or content that is particularly popular.

Worth highlighting is the value of spatial audience data that can be collected in the auditorium which can be used to deliver a bespoke experience depending on a number of factors. Our earlier work considered, for instance, the design of bespoke layout for an immersive experience.

In one of our models, the audience would be allowed to choose their seats, which could from an operational point of view have advantages. Having this said, not all seats would potentially provide an optimal viewing experience. Furthermore, story-dependent or interactive content might not be equally displayed on all screens, meaning that there is a certain hierarchy of screens for each show. Sensor data that can read where an audience is seated or standing, could trigger on which screen shows story-dependent or interactive content, giving the audience a maximal sense of freedom (choice of seat), while also an optimised viewing experience.

v. Overt Audience Interactions

Our second type of audience interaction considers arising interacting possibilities if the audience is aware of their participation. In fact, **Overt Audience Interaction** (OAI) are designed in such a way that they seek the attention of their single participant or multiple participants. These types of interactions can again find a wide range of applications, not just inside the immersive theatre, but also before and after the show.

Before the show, such as during ticketing or waiting in a queue to enter, the purpose of such interaction scenarios would be to offer the opportunity for guests to familiarise themselves with the characters or their storyworld. This is important as one would expect that not everyone coming to this immersive experience might be familiar with, for instance, *Shaun the Sheep* and all of his friends in the flock.

	<i>Location</i>	<i>Purpose</i>	<i>Example</i>
Before	Ticketing; queue line	Familiarisation with characters and storyworld	Screen-based story character welcomes audience and shows direction
During	Auditorium; immersive theatre	Sharing a space with characters and storyworld	Character asks to help resolving a problem inside the storyworld
After	After show assembly; cafe; souvenir shop	Building up a personal relation with characters and storyworld	Screen-based story character offers to take a selfie
Remote	Away from theatre; private or shared public spaces	Continuing and deepening the relation with characters and storyworld	Story characters continues to share their experience on their adventure
Covert Interaction	Ticketing; queue line	Content/Delivery Optimisation	
Overt Interaction	Auditorium; immersive theatre	Individual/Group Interaction	

vi. Audience Movement Tracking

In technical terms, we proposed that our audience interactions in immersive, physical environments are enabled by sensors carefully positioned in the auditorium space. Generally speaking, we suggested using optical camera sensors or laser, infrared or LiDAR methods of tracking user position in the immersive space, which has the advantage that it can also resolve limb movements for gestural tracking and touch-based interface deployment.

An array of optical cameras could, for instance, observe user positions in the immersive auditorium. These cameras could be combined with software designed to track user position, such as *OpenCV* (Bradski 2000).

Microsoft's *Azure Kinect* optical and infrared depth sensing cameras were selected as a proposed method of tracking an audience member's body position as they approached, for instance, a projection screen. The device's depth sensing capability allows a single sensor to accurately measure the position of a user and to measure their speed of approach and change in location over time. This would allow more accurate measures of a person's body allowing for more nuanced interaction scenarios than the optical sensors used in the *Covert* data capture scenario.

Users could then interact with on-screen characters with their hands used to make gestures which could be interpreted by the digital characters and trigger a response.

The *Azure Kinect* device is also capable of tracking multiple users simultaneously; this capability could have enabled cooperative interactive challenges for multiple users. Data acquired from these interactive scenarios would reveal insight into individual propensity to interact with content.

Furthermore, it could shed light on how certain characters appeal to the audience by, for instance, analysing the changes between different demographics.

The gathering of overt information could give content providers, such as Aardman, valuable information on what characters appeal to different age groups when given the opportunity to interact with a range of characters.

Another body tracking solution we have investigated is the *Zed Sense 2i* is a depth camera using stereoscopic technologies and AI models for body or object detection. The body tracking is based on a neural network and produces a 34-joint body. It can detect multiple bodies in space. It can also detect non-human objects giving data and speed data. This opens up the opportunity to track props in the space as the audience interacts with them.

It has a 120-degree wide view, which makes it very suitable for large-scale installations, but it has been shown to be slightly less accurate than the *Kinect Azure* in body tracking, which we also found in our own investigations (Sosa-León et al., 2022: 3798).

vii. Machine learning and Interaction

We wanted to investigate how we could utilise the advancements in machine learning to enhance the interactivity and storytelling of the experience. To create compelling interactions that happen in real-time with a real sense of agency for the audience within the story, where they feel they are affecting its outcome. Machine learning is being used throughout interaction design to innovate interaction for immersive technology, enabling more real-world interaction styles.

Body movement

Movement is how we interact in our daily lives with people and objects, reflecting this reality-based interaction style is an ideal form of interaction for immersive experiences (Jacob et al., 2008, pp. 201–210). When your movement has an effect in a virtual world, it increases your sense of presence (Slater, 2009). It is extremely difficult to write code that will recognise complex movements; however, machine learning can be used to recognise poses or sequences of movements (Hilton et al., 2021, pp. 1–10). By using recordings of people's body movements for training, we can accurately detect the audience's movements and match that to character

responses or triggering story arcs. This could be used for group or individual interaction to interplay between the audience and the story being told. Data could be collected during testing the experience as well as throughout the experience to improve the models.

During our research, we worked with the Azure Kinect and the Zed Sense 2i to do initial testing of movement interaction with the experience set-up. Both cameras are able to connect with the Unreal game engine to directly input their movement data into the gameplay. Testing was done using InteractML, a tool for designing movement interaction quickly and efficiently (Hilton et al., 2021, pp. 1–10). You are able to quickly record examples of movement and connect these to outcomes in the system. This tool enabled fast model training and movement processing needed for real-time interaction. Using both cameras, the system could pick up multiple bodies and predict if they were doing the same movement. This output was then used to trigger different interactions in the environment.

Sound

It is easy to detect volume changes in sound to create interactions that respond to audience speech. However, to create a more compelling experience, machine learning can be used to recognise exact words using speech recognition. This could be used for individual audience members or for a whole group interaction. Audience members could answer characters in the experience to decide what is going to happen next or control certain parts of the experience. Speech recognition has vastly improved over the last few years and is now embedded in our daily technology with many different methods for fast real-time results (Yu et al., 2022, pp. 1474–1482). Voice interaction is a compelling way to get audiences to make decisions in a natural way for immersive experiences (Monteiro, 2017, pp. 2702–2713).

Vocal emotion can also be recognised using machine learning techniques; deep learning techniques have been used across languages with impressive results (Khalil et al., 2019, pp. 117327–117345), (Lee et al., 2022) The models are able to detect anger and boredom, disgust, surprise, fear, joy, happiness, neutrality and sadness. They are also able to detect this on arousal (intensity or activation of emotion) or valence (positive or negative). This could be used in the context of character interaction, for example, if the

audience is asked to exclaim excitedly or warn the character that something is coming. The majority of research that has been done on this recognition has been done on individual data; research would need to be done into group vocal emotion recognition.

Object Detection and Movement

Machine learning can also be used for object detection. This was tested with the Zed sense 2i giving promising results for being able to tell the movement and speed of the object. Once such use of this could be for the torch interaction where the audience can illuminate part of the scene in real-time. This could be used in many other ways to bridge the gap between the screen based interaction and real-world enhancing the sense of immersion. This could also create compelling interaction within the audience where they can interact with each other through physical objects.

Non-Player Intelligent Character

NPC's (non-player characters) is an area for future investigation for this project. There have been huge recent advancements in AI which is set to revolutionise how characters can respond to input. Several companies concentrated on developing this technology such as Inworld and Replica are receiving significant investment and publicity. Future research could develop NPC's with the personality and humour of the characters in Shaun the Sheep.

viii. Key Objectives of Interaction Scenario

When developing interaction scenarios within an immersive 360 degrees environment and a mobile audience, one is essentially designing inside (interfering with) a system of high complexity, even before adding any audience interactions. Designing such scenarios means operating in an environment that has a lot of dependencies and interdependencies; in technical, but also spatial and experiential terms. We, therefore, formulated three key objectives prior to embarking on this process.

From an audience perspective, our interaction scenario should link the following aspects of the visitor attraction:

To link space and interaction

We recognise that our immersive theatre is essentially a box that can simulate spatial environments. When designing an audience interaction, it is therefore important to make use of this unique characteristic as much as possible. Furthermore, we recognise

that people and their re-/actions are the defining features of this immersive space.

To link interaction with immersion

We recognise that an audience interaction should not become a means to an end, but instead present itself as a key driver of our ambition to create a sensation of spatial and narrative immersion. We operate on the assumption that audience participation will have a dependency on the individual's feeling of being immersed and vice versa.

To link immersion with fun.

We recognise that we must not lose sight of our ultimate goal, which is to create an entertainment offer that would be fun for a family audience. We believe that this can be achieved in a variety of ways, including a robust story integration, humour, a positive crowd experience and a bodily sensation, based on action > reaction > reward.



ix. Realtime Participation Scenarios (Overt)

We identified and developed bespoke scenarios which would allow our audience to knowingly interact with screen content in realtime, which we considered to be an essential part of the audience's journey through the story. It is important to highlight here again the interconnectedness of areas we considered. To design realtime participation or even interaction scenarios for the audience in this space was not part of a linear process. These scenarios could not be developed on their own without considering other key parts that made up the immersive experience, such as the presence of other people, audience member spatial position, screen content, audio and so on. Having this said, we needed to find a mechanism of selection and elimination that would help us to identify participatory or interaction moments for different kinds of audience engagement scenarios.

We found it fruitful to start by identifying suitable moments in which interaction scenarios could occur. Our natural starting point for this task was to go back to the story, which for the main part was linearly organised. Having this said, and as it will be highlighted later, this process required a non-linear approach in the design of the entire experience. As a starting point, we divided our story into fragments that in principle would support audience participation; each of which would then be collectively scrutinised for participation and interaction scenario opportunities and possible problems in the realisation. The range of ideas we collected were wide and fell into the category of Overt Audience Interaction (OAI) as discussed earlier.

A small selection of principle examples discussed included:

- Touch screen interactions (cubes) that would trigger an event in the space or story
- Stepping on floor areas that would trigger an event in the space or story
- Shouting/waving that would trigger screen actions, such as a character to respond
- A torch which, when tilted or moved, would light up specific areas within the scene
- Mice projected onto the floor which would respond to the presence of the audience

Many scenarios were considered during this phase of our project. What was interesting was that this process, in turn, stimulated conversations around the story development, meaning that newly developed interaction scenarios would impact or change aspects of the story. "Would it not be funny if when the audience does XYZ that then Shaun/Bitzer would do that?" This highlights the non-linear process once more and illustrates how much our project departed from the normal development of a Shaun the Sheep episode produced for a non-participating audience in front of a single screen.



Fig.11: Set up of experimental virtual, interactive torch, illuminating screen content in realtime.



Fig.12: Experimental setup to test scale relationships of virtual characters waving at an audience.

x. Interactive Rope Pull

To illustrate our design and implementation process slightly better, it might be helpful to focus on a particular scene. In a key moment, the story required audience members to pull a rope to move the scene forward, this action would be encouraged by the virtual characters in the story. We identified and selected this rope pull from our storyline as a potentially effective participatory moment that would allow us to activate the final segment of screen events in our barn scene. The development of the 'Rope Pull' interaction included several stages:

Stage 1: Producing a character animation showing Shaun giving instructions to the audience. Producing a second character animation showing Bitzer being attached to virtual pulleys and a rope.

Stage 2. Integration of Aardman animations into *Unreal Engine* scene, paying attention to scale, alignment and timing.

Stage 3. Connecting *Unreal Engine* to an Arduino controller. The Arduino provides control of the animation. As the rope is pulled inside the physical space, the virtual rope tightens before twanging Bitzer through the roof.

Stage 4. Setting up a physical rope in the auditorium that connects to the virtual pulleys. A physical rope setup (mockup) was connected to the Arduino board, which was in turn connected to the *Unreal Engine* scene.



Fig.13: Experimental setup to test rope pull interaction [images lain; Arduino controller]



Fig.14: Experimental setup to test rope pull interaction [images Iain; Arduino controller]



Fig.15: Experimental setup to test rope pull interaction [images Iain; Arduino controller]

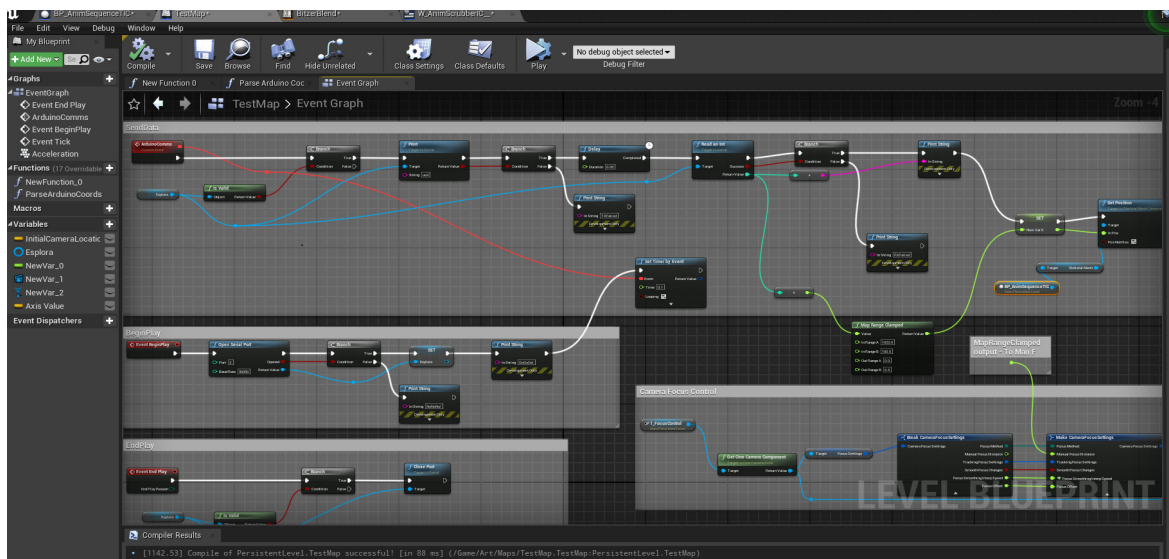


Fig.16: Unreal project setup for rope pull interaction [images lain; Arduino controller]

xi. Vertical Descent

The second example of an interaction scenario was called vertical descent and it was considered by the team because it was particularly challenging and raised several unanswered questions at the time about whether it would be realisable or not. The idea was developed on the assumption that it would be fun to not only develop simple on-screen interaction scenarios but, since this is an immersive experience, develop a scene that makes use of this being a spatially immersive experience, capable of stimulating our senses. While the main attraction of immersive environments stems mainly from simulating a presence in a space, we recognised that our setup would also be able to simulate a virtual travelling through that space. What sounds simple as an idea at first glance, produces problems we did not encounter before and which we were keen to tackle, regardless of whether or not the results would be suitable for a public show or not.

To design and develop the mechanisms for this scenario, which again aimed to transgress the boundaries between physical and virtual spaces, we produced a series of diagrams. Such diagrams, which were

not too dissimilar from storyboard, were key to communicating the ideas within our team and partners and provided a natural link to our story. This interaction scenario was also interesting because it considered the interaction of a group of people, rather than focusing on an individual member of the audience, like in the rope pull mentioned before. Once enough people would step onto the platform, a simulated elevator (physical action) would transport the audience down to the lower ground (virtual reaction) where more details of the set design would be revealed and the story would continue. During testing, we were particularly interested in the physiological effect such a setup would have, which is why we produced a full-scale mockup in VP studio to test such a travelling through space effect.

We came up with the concept of a double-height barn in which, at the start of the scene, the audience would find themselves on the upper floor.

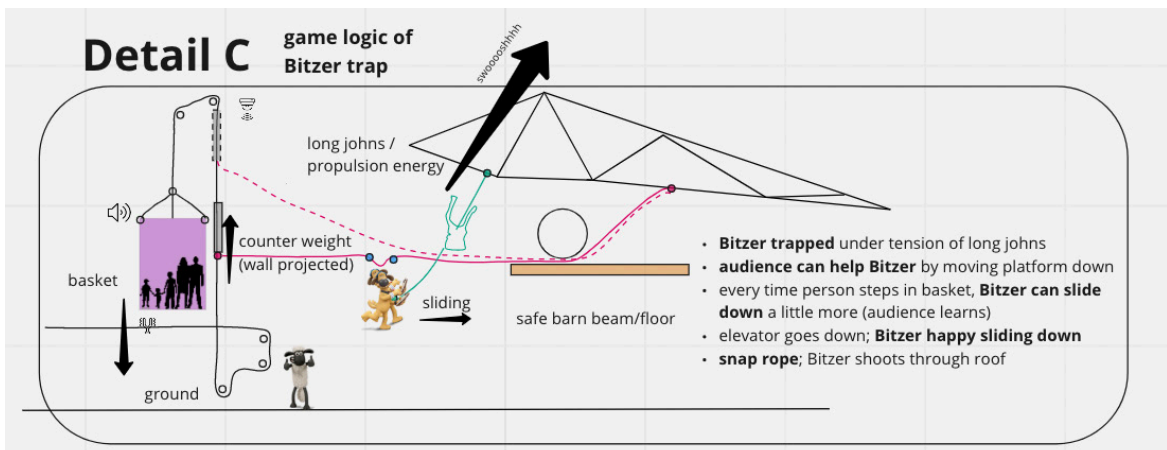
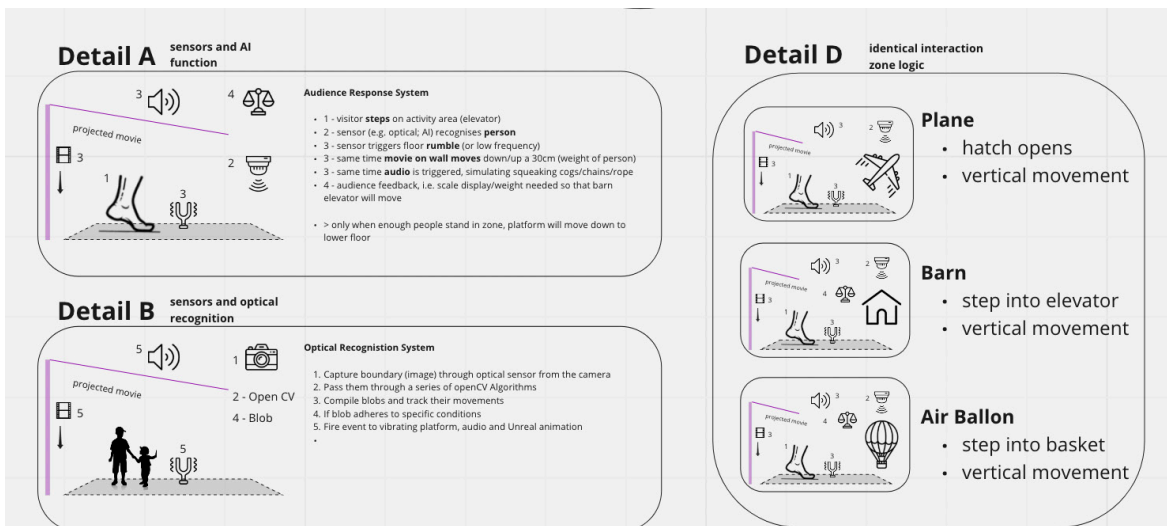
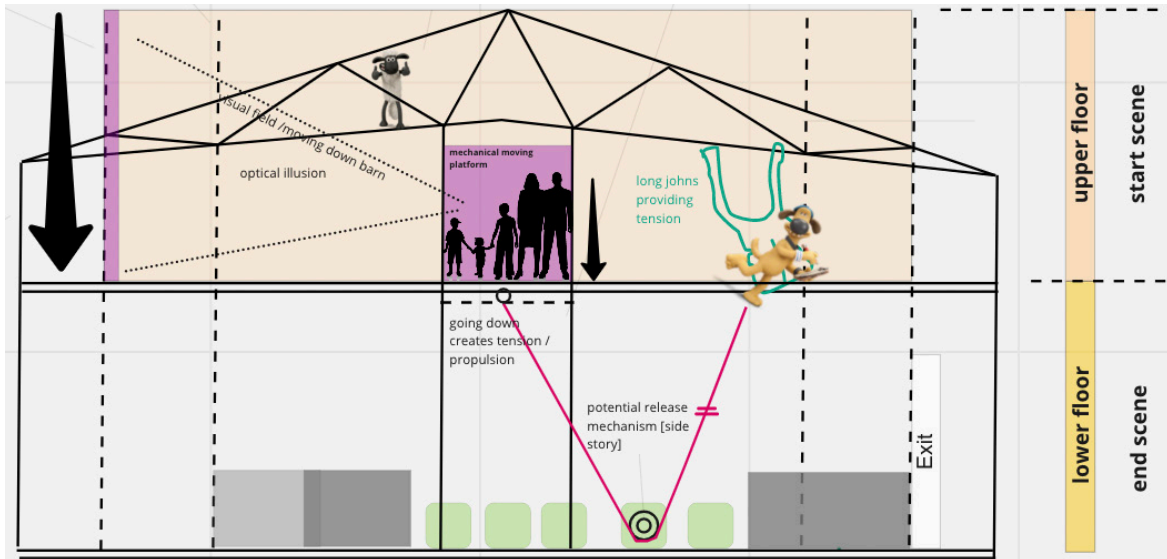


Fig.17: Diagrams explaining the mechanism and techniques used in a particular interaction scenario.



Fig.18: Stepping onto the platform before travelling down with a grain elevator



Fig.19: Experimental studio setup simulating an audience being on the upper floor of a barn, with a wooden platform marked up in the centre

xii. VR Simulator of Large Scale Multi-person Immersive Installations

Due to the Covid-related impact on our project, we decided to work on the majority of our R&D questions in VR instead of building a physical studio for testing. We, therefore, started to build a VR simulator for a large-scale multi-person immersive installation using both *Unreal Engine* and *Unity*.

What started as a necessity in the first place, in fact, proved to be a rather useful approach, which can hopefully also be applied to other projects in the future.

In fact, working in such a way helped us to expose and test problems which would only become clear by using this VR simulation.

Our principal objective with this was to identify and test an effective, collaborative, multi-user workflow process, that would allow us to work collaboratively and remotely and various specific research questions that related to the perceived quality of the immersive experience. We first tested to build such a simulator using *Unreal Engine*, which has a multi-user editing feature. One of our aims was that this would allow content creators to collaborate remotely by allowing them to edit the same project simultaneously over networked connections. In order to do this, we had to modify our *Unreal Engine* desktop application to support such networked connections in VR.

Our rationale here was to enable collaborative remote creation of Aardman animated scenes, which could subsequently be imported into an approximation of the proposed test XR lab/auditorium space.

Using a defined moment in the story as a test case, the audience would be prompted to interact with a narrative exposition to advance the story content. In doing so, we intended to test and evaluate the mechanics underpinning certain interactive animations even before the construction of the physical XR lab environment was completed. (See *fig 6* and *7*)

To build a VR environment in *Unreal Engine* also was initially appealing, also because of the visual fidelity that can be achieved, which can be rendered out to the quality of the finished audience experience. For the next stage of our development, however, our emphasis lay on isolating problems that we identified, being able to do rapid prototyping, and simplifying testing conditions with untethered VR equipment. We, therefore, created a second VR Simulation of the XR lab and final user experience auditorium space; this time in *Unity*.



Fig.20: Experimental studio setup simulating an audience being on the upper floor of a barn, with a wooden platform marked up in the centre

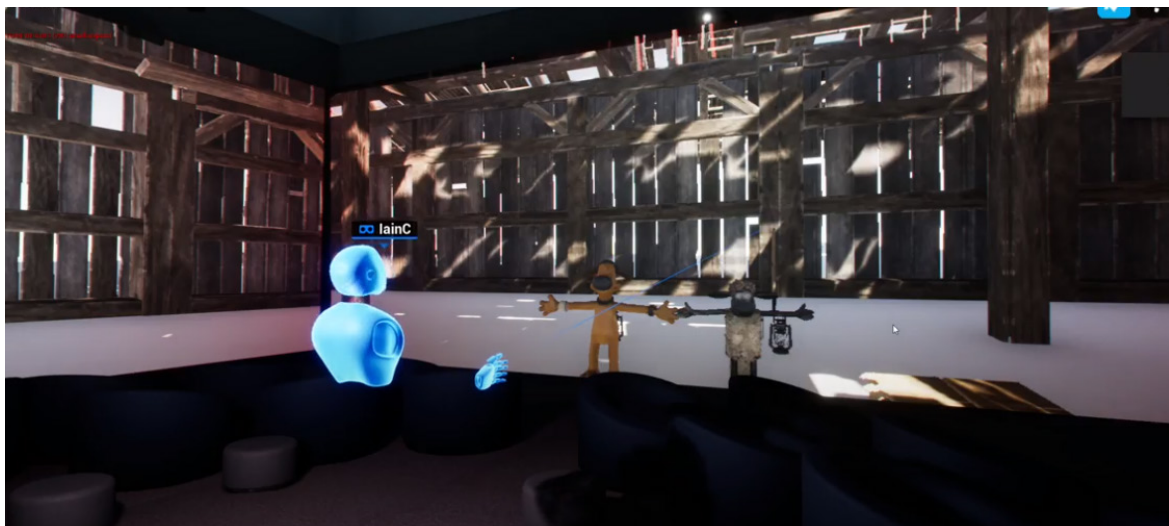


Fig.21: VR testing of interactions inside virtual environments with online avatars, using Unreal Engine

xiii. VR Audience Testing

The innovation of the design of our test VR installation lies in the fact that we did not create simply a VR installation, as a means to an end (i.e. end-user product), but as an environment that would be able to isolate, simulate and test all kinds of arising problems that would occur in a location-based, immersive experience. Key questions arising in our case, for instance, related to alignment issues (projected image), perspective distortion, audience position; perceived immersion and user engagement. The questions that we, therefore, formulated in our investigation included:

- **Perspective Distortion:** What level of distortion would the audience experience while moving around in such a projected space?
- **Sense of Immersion:** What level does perspective distortion affect the experience (e.g., immersion)?
- **Distortion Mitigation:** How could arising distortion effects be mitigated?
- **Audience Behaviour:** How can the audience be encouraged to move/stay in the centre of the space?
- **Engagement with Characters:** How immersed and engaged do people feel with characters?

To answer these questions accurately, we needed to find a way to simulate the spatial conditions of the installation. To build, however, a full scale-set would require a large amount of time and resources and, due to Covid proved to be impossible. We, therefore, created a series of Unity scenes in a virtual reality that replicated the conditions of the physical location, enabling us to prototype various spaces and set-ups quicker and cheaper.

xiv. Technical VR Setup

In simplified terms, we began by setting up a Master scene in *Unity*, consisting of a square space (barn) with a smaller square platform in the centre. The replica scene of the actual location consisted of 5 video planes, simulating the 4 surrounding walls and a floor projection of our physical location-based setting. We added a virtual reality rig to the centre of the space, which allowed us to align and scale the projections to the exact scale of the proposed physical immersive auditorium. We used Aardman's bespoke 3D models of the prototype *Shaun the Sheep* world, which was set up in a separate Unity scene. This second scene was filmed from 5 camera angles.

Using Unity's recording feature, we were able to stream the content onto the walls and floor of the Master installation simulation.

Initially, a lightweight project was set up for the Quest 2 headset, which comes with the added benefit of being untethered for potential user testing. As the project grew in test scenes, complexity and interactions, however, we felt the need to upgrade our testing equipment to higher processing power and fidelity. We noticed that the aliasing and quality of the visuals somewhat interfered with our ability to understand the implications of perspective distortion. We, therefore, moved to using the Vive Pro 2, which we found to have the best video quality for our purposes, nearly matching the visual quality that we would see in our proposed large scale projections.

We decided further to record our video streams in the same resolution as the Vive Pro 2 headset, which significantly reduced disturbing aliasing effects. The following will describe 3 sets of tests to explore different elements of our investigation.

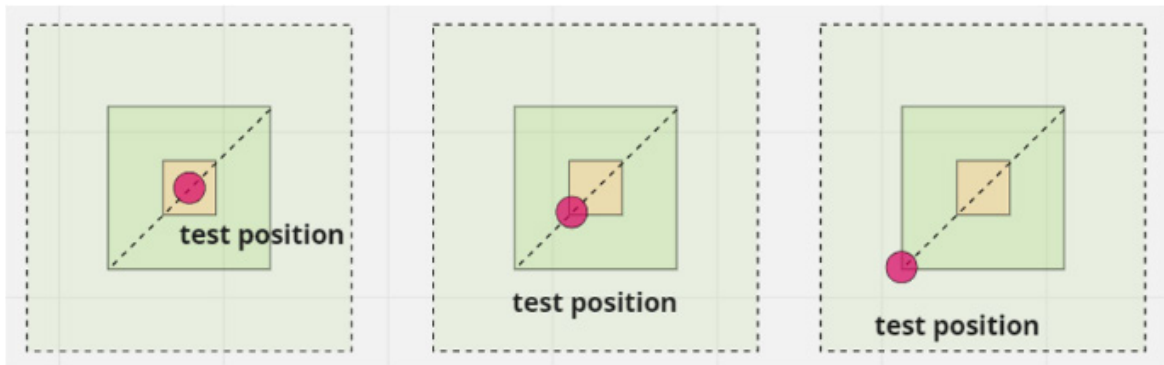


xv. Distortion & Immersion: Down Movement

In initial tests we noticed that distortion effects appear to be particularly pronounced when the audience is moving in our space; horizontally as well as vertically.

The latter vertical move appealed to us to be particularly worth further investigation. We, therefore, created a VR interaction scenario in which the audience can trigger a vertical descent of a square platform in the centre from a higher to a lower barn level, potentially exposing extreme cases of distortion.

We created video footage that we projected into our walls inside our master Unity scene which simulates such a vertical descent. What we were interested in was the point of view (POV) of an audience standing on our moving inner square platform as they were moving down, hitting the floor, seeing the barn collapse and revealing the natural landscape surrounding the barn. We decided to focus on 3 variables and how these would affect distortion and immersion.



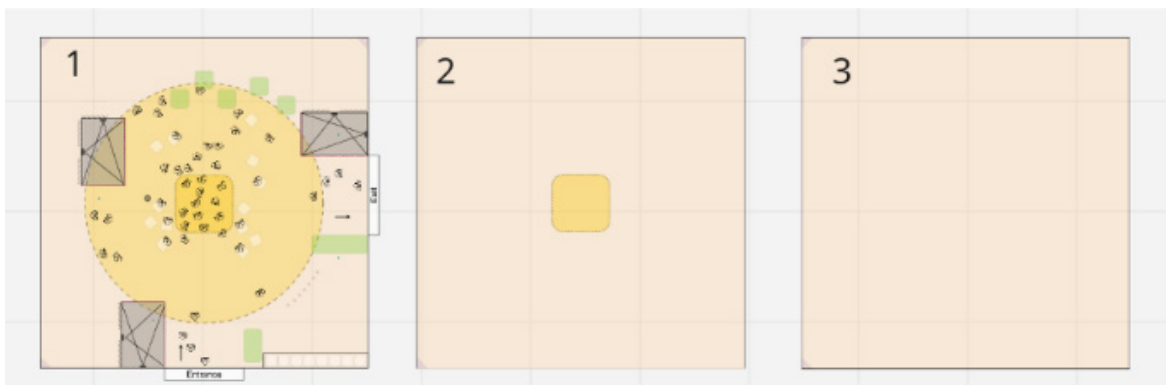
1. **Position of the audience member in the barn.** We tested three positions: centre, corner of the platform, corner of the barn. This would give an understanding of the best, middle and worst-case scenarios.
2. **Size of virtual barn in relation to projections.** We tested three sizes of barn 15 x 15m matching the exact projection room size, 20 x 20m and 30 x 30m. We noticed that a larger virtual space gives us more room for character animations, yet we needed to test how this affected distortion.
3. **Objects in the virtual barn.** We tested two scenarios one with and one without objects to see if the objects helped with distortion or increased its effects.

xvi. Audience Movement & Distortion

We learned from previous testing that the worst distortion is experienced from the edges of the projection room and were looking for ways to mitigate this. In our next set of tests, therefore, we designed a set of VR scenarios that explored how we might encourage the audience to stay in the centre of the room, as far away from the projected screens as possible. We created a scene showing the virtual barn in its collapsed state revealing the outside of the barn. It was important to give our test audience a maximum sense of freedom to walk around as freely and unmediated as possible. Instead of using a common VR convention – which is using handsets to point, trigger, and teleport – we translated the user's direction and arm movement into a movement inside the VR space. This also had the advantage that we did not need a 1:1 scale replica of the simulated space to test, as users essentially could

walk-in-place. The emphasis in these tests were entirely on the architectural setup and design of the barn space and landscape.

We wanted to understand how design elements and the setting itself would impact the movement behaviour of an audience. In the first architectural setting, we simulated an earlier developed proposed plan for the immersive theatre, which included several seating options and props. For the second, we removed all physical objects of the set design and instead replaced it with a glowing square in the middle of the scene, which could be achieved by a projection from the top of the auditorium. Our third and final set, was entirely empty, with no centre floor projection, only offering the architectural parameters of the barn and landscape beyond as points of reference.



1. **In the first scene**, there are white blocks in the unity scene to guide movement around the space.
2. **The second scene**, there are no virtual objects but there is a glowing square in the middle of the scene.
3. **In the final scene**, there is just the virtual barn.

These scenes were analysed to see how audiences can be encouraged to move by the setup of the space.

xvii. Character Engagement and Immersion

In this third part of our experiments, we investigated whether it is possible in our proposed immersive experience that an audience feels immersed, in the sense that they are sharing a space with the characters in a particular scene and how the characters simulated movement through their shared space might affect such a sensation. We think that such a sensation – to transgress the fourth wall and with it the idea that characters do somehow occupy the same virtual/physical space – would be quintessential in terms of achieving our earlier definitions of spatial as well as narrative immersion.

In this test, the audience stood at the top of the barn, where they would see Shaun the sheep appearing. He would wave to the crowd and then swing across the barn from one side to the other. In test a) he would swing from left to right and test b) from front to back swinging above the participant's heads, who would be facing to the front. In order to heighten our desired effect, we have experimented with additional special effects, such as floor projections and spatial sound in order to increase the sense of immersion. Both tests gave us insight into how such a swing movement of Shaun affects the participants' sense of being immersed and indeed feeling that they somehow would share a space with an on-screen Aardman character.

• Summary of VR Audience Testing

In total, we managed to design 27 different scenes that we split into two halves. The first half of these tests were dedicated to test I. – Distortion and Immersion and 2. Audience Movement and Distortion, which were randomly ordered to avoid bias in how familiar the audience was in the scene. The second half was dedicated to III. – Character Engagement and Immersion tests, which were also randomly ordered. The full VR experiment took approximately 25 minutes and participants were given an option of a break in the middle. Results from these tests are currently analysed and published in the future.



VI. Remote Experience

i. Background to this work package

In response to the COVID-19 pandemic, the AHRC gave us the opportunity to add a discrete work package dedicated to a remote experience dimension of the location-based Shaun the Sheep project. It was motivated by a need to consider how aspects of the parent project could be reimagined in light of the restrictions of people's movements and gatherings. Changing the context of this work package from a mass audience, site-specific immersive experience to one that a single user would experience on their mobile phones required a fundamental re-think. One of our first considerations was how

to best align this project with the larger visitor experience as there was a risk that ongoing COVID interferences on progress of the overall project could also affect, through newly created dependencies, the development of the remote experience element. We, therefore, decided that the remote project will need to be conceived as a project element that can be run independently from the parent project. We appointed FeedAR to lead the project in collaboration with Professor Koeck and the Aardman team over a period of eighteen months, culminating in a conference demonstration in London in January 2023.

Project Scope and Deliverables of the Remote Experience

Shaun the Sheep Remote Experience aimed to create genuinely new and innovative ways of engaging online audiences in China with a story-based animation content that could be linked back to the parent project. Our key research question related to how to realise such a challenge. We were mindful of the fact that the mobile market and access to platforms in China is different to that in the UK, which would require consideration. In conversation with Aardman, it was decided to develop this work on an open platform – in this case “browser- based” – which would allow for the widest possible access without locking the project delivery into a particular App Store or media channel for mobile media distribution (iOS/Android). Instead, we recognised that WeChat is a powerful mobile platform in China, which would require our special attention. Our principle aims for a remote user experience were as follows.

1. To delivers responsive entertainment in realtime;
2. To conceptualised and built as a sharable experience;
3. To provide an individualised, tailored experience;
4. To make the experience deployable for large/mass audiences in the Chinese context.

The brief's modest budget and broad scope meant it would be impossible to create a fully realised single prototype. Instead, our approach was to develop a single high-level concept in the initial discovery phase into which we could build on. This concept provided a framework to explore and research the key deliverables. We created mini work packages to validate this concept's elements (sub-research questions) by creating multiple small prototypes of varying technical complexity and creative fidelity. Much of the decision making behind the prototyping was motivated by a desire to innovate and try new approaches.

Secondary Research Questions

- How can a sharable remote experience integrate within a WeChat ecosystem and the web?
- What was the potential to monetise this approach? What cultural and practical issues did this raise within the China context?
- How far can we push the fidelity, interaction and animation of WebAR?

Mini Work Packages

In order to address our secondary research questions above, we decided to structure our development into discrete parts which would address specific R&D challenges, which we called Mini Work Packages (MWP).

MP01	Can we successfully send a virtual package across China using WeChat, incorporating the help of, e.g., three other users?
MP02	What assets can we reuse from the parent project? (Audit)
MP03	What analytics are available via the WeChat platform? (GAP analysis)
MP04	How can we make a financial transaction with WeChat? (Test micropayments)
MP05	How can we be sure our AR will work across the main android browsers in use in China
MP06	How can we make an experienced cross from WebAR into WeChat (Html)
MP07	Develop the underlying physics side of game
MP08	Develop Low fidelity game prototypes
MP09	Develop low fidelity WebAR game prototypes
MP10	Develop one or two games creatively, and higher fidelity
MP11	Work on Narrative
MP12	Make a full, but low fidelity user journey that brings all prototypes together
MP13	Workshop with Aardman to discuss creative and art direction
MP14	Take Shaun model from parent project into remote project

Project Sprints

This list of mini-work packages was then distributed across six sprints, each approximately 2-3 months. At the end of each sprint, the project team got together to discuss and work out what the focus of the following sprint would be.

- **Sprint 1:** Initial response and a high-level creative concept that answers the brief and deliverable requirements: Discovery.
- **Sprint 2:** Exploration and research of China context (particularly sharing) WeChat.
- **Sprint 3:** Validating WeChat integration with WebAR – using technical prototypes.
- **Sprint 4:** Validating the game and interactive elements of the concept.
- **Sprint 5:** Refining into two prototypes to explore new animation techniques and WebAR fidelity.
- **Sprint 6:** *final prototype to bring aspects of previous prototypes into a single interactive, including computer vision.*



ii. Sprint 1: Discovery Phase

Our initial work package looked at the project as a whole and set out to develop a high-level strategy that could help the wider team understand the scope and see what a remote experience might look like. In doing so, everyone from the wider team was able to gain an informed perspective and could contribute constructively.

Our discovery phase led us to formulating a distinct approach that would focus on pushing the boundaries of using web technologies.

Our objective was to create a game that would combine **physical gameplay** (experiential) with a **shareable experience** (task-driven multiplayer). The result from this work became the basis of a creative concept which we called **The Accidental Sheep Delivery Service (ASDS)**



Fig.22: Illustrating the potential for WebXR to present a porous experience across multiple mediums and timelines compared to the more conventional single native application using Aardman's "Big Fix Up " as an example.

Taking a web-based approach to creating a porous gaming platform/experience

A fundamental question when working on a project delivered via mobile phone is whether to use the conventional method of developing a native application or to look at more open web-based approaches. A relatively recent technique that we wanted to explore was Progressive Web Apps (PWA); these are apps that are highly elastic and increasingly designed for creative applications that can, for instance, integrate data from IMU sensors, gyroscopes, cameras and more. PWA's use emerging web browser APIs, device features, and traditional progressive enhancement strategies to bring a native app-like user experience to a cross platform web application. WebAR is an even more recent development within a PWA. This uses third-party services like 8th Wall to provide augmented reality (AR) experiences through a standard browser. In addition, the third parties use their servers to interpret the camera feed and IMU data to provide AR features usually reserved for native applications.

The main advantage of a PWA is that it removes the barrier of installing an application on a mobile device from an app store. However, we also wanted to

explore other advantages of this approach. Specifically, we have argued that working with web technologies creates a much more open platform that can “break out elements” and create an intrinsically more shareable experience.

In order to demonstrate the advantages and nature of a web-based experience compared to a conventional App experience to Aardman and the wider team, we used the example of the recently launched (2021) Aardman mobile AR app, *The Big Fix Up*. The app development was funded under the UKRI's Audiences of the Future immersive demonstrator program and was familiar to the Aardman team. By reimagining this project made with web app technology, we showed how the various elements of the gameplay within the native app could be split out and become individual elements that could be deployed across multiple channels (social media, web, SMS). This would make each part of the gameplay sharable and potentially a multiplayer experience. We called this a more porous web application that could be split out and played across multiple timelines and players.

Physical Game and Shareable Play

Shaun the Sheep has no dialogue and relies on slapstick and physical humour, which focused our attention on researching a physical gameplay approach. We looked particularly at early Nintendo Game & Watch devices from the early 1980s as inspiration. More modern games like *Angry Birds* (2009) also had that physical and addictive gameplay that we felt should be a significant component of the remote experience.

The second inspiration was our multiplayer and shareable web-based game came from Rob Bevan and Tim Wright's seminal web project *XPT Parcel Delivery Service* (2000). Carlyne Ellis' article (Need to Know: Tim Wright, 24 Jul 2000, Guardian Online) describes the principal gameplay in the following words.

'Virtual gift giving. Go to IT3C.co.uk and select the person you want to send the gift. It throws up the gifts we think appropriate, and you select one with a message to send with it. It is a sort of enhanced greetings card service, full of funny gifts and incidents, and it triggers a four-day narrative, a spoof of a dot.com package delivery. A way of communicating with people and providing entertainment. Also a digital glue for sticking people to our products - the more information you give, the more tailored the characters and plot lines.'

The principal intention behind the game and mechanism, as outlined above, deeply resonated in our team. It led us to make the notion of shared experience central to our own gameplay and not simply a more typical added on option. As such, Bevan and Wright's XPT project provided an entertaining and relevant example of how this can be done. It showed how we

could combine virtues such as sharing and collaborating into something that had the potential to be scaled up for a large audience. It also provided us with food for thought of how a game could be taken out of the context of a single instance.

In summary, we began to understand how a piece of our gameplay could be broken up into smaller elements that could be experienced on different mediums at different times – yet, the sum of these individual parts would still provide consistency to tell an overall narrative. Furthermore, we decided to make sharing central to our gameplay. For instance, the person one would share our game with could be introduced via a game element, unlike other shared game elements that involve the sender being the protagonist. Overall we concluded that combining an addictive physical game mechanic with a strong community focus felt to be on-brand with Shaun and culturally aligned with a Chinese audience.



Fig.23: References for the physical and shareable game-playing approaches

Accidental Sheep Delivery Service (ASDS)

In order to communicate what the technical and creative approaches and references detailed so far might look like – in the context of a Remote Shaun the Sheep Experience – we came up with the ASDS creative concept. Following the line that the location-based project took, our remote concept was rooted in a story, developed as a pivot from the main narrative, which includes a scene playing on an aeroplane.

- **ASDS Basic Storyline**

Our story starts on an aeroplane. One of the flock is stuck and, by the time they fall out of the aeroplane, they are on their own. Luckily, they spot a pile of cardboard boxes that previously had also fallen from the aeroplane on the ground and use them to break their fall. Unfortunately, in the process, some boxes break open. They find balloons, a rechargeable leaf blower and a beautiful ornate gift with a birthday card.

Their heart is melted by the thought of somebody not receiving their precious gifts. The flock works out that by blowing the balloons up, they can make themselves float and by using the leaf blower, they can propel themselves to deliver the gift on time for the birthday.

Game Mechanics and Timeline

The mobile experience starts with a short movie that serves as an introduction to the basic story. The film can be viewed flat or as a 360-degrees video that can be seen via moving a mobile phone as a home-based/remote experience.

- **AR Experience**

The user is then directed to point their phone's camera at a table, where they can see cardboard boxes that they need to catch and create a pile for a safe landing of other sheep.

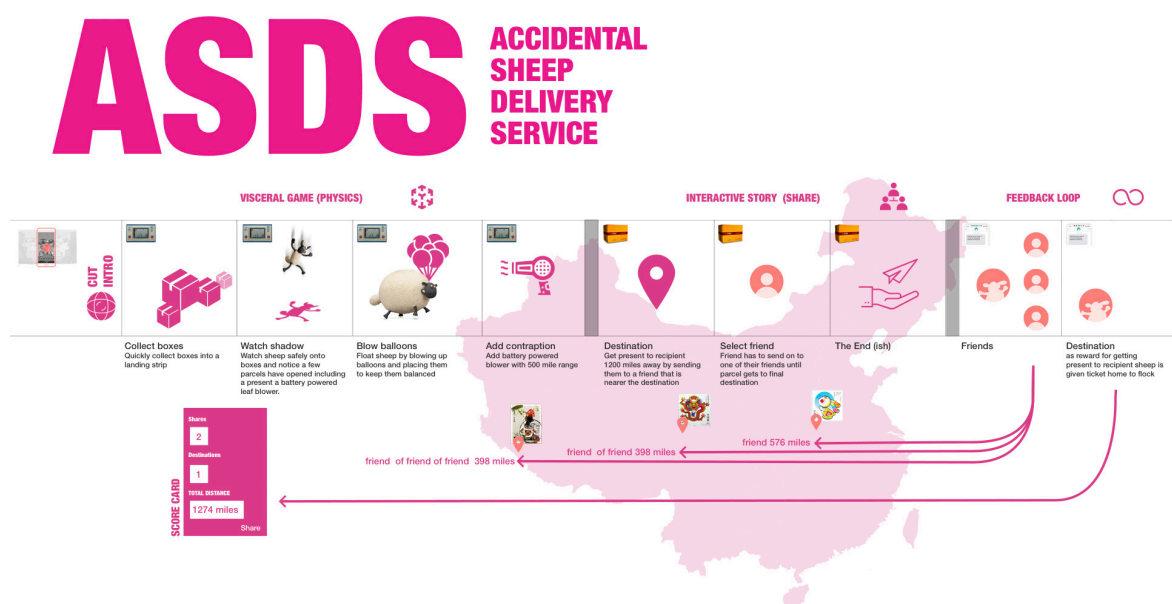


Fig.24: Schematic of the Accidental Sheep Delivery Service concept

The user then will see a shadow, gradually getting larger, followed by a sheep that is landing safely and breaking open some boxes.

Well done they saved a sheep from certain death...

Next, the user is then instructed to blow up some balloons to make the sheep float. This interaction is achieved by blowing into the phone microphone and placing the balloons on the sheep to ensure they are balanced and floating at a steady height.

- **Sharing Experience**

Users then have to deliver the parcel to X, which is however out of range of the leaf blower that they have. Hence, they need to select a contact that lives in that direction who can help. The user is instructed to enter an email and message to a friend.

- **Post-experience**

The user receives notifications and mileage updates from the ASDS.



iii. Sprint 2: China Context

MP03: MP04: MP05:

To develop a remote experience for a Chinese audience presented one of our biggest unknowns. By making this our second sprint, it allowed the wider team to reflect on the outcomes of Sprint 1, whilst the core development team could focus on understanding and researching the Chinese mobile market context.

How people use their mobile phones and consume the internet is very different in China from how they are used in the West. Many social apps and elements we take for granted are unavailable in China (e.g., Facebook, Google, Instagram). We, therefore, had to find a dissemination strategy that did not rely on native Apps, and which would work and could be adopted widely in a Chinese market.

Our focus of the research fell on WeChat, which is by far the dominant way Chinese users spend time online with their mobile phones. Our research started by learning more about its opportunities, limitations, and typical user behaviours.

Headline findings of WeChat Ecosystem

- WeChat is the dominant platform for people to interact online in China.
- WeChat is the dominant way people make both online and physical purchases.
- WeChat has a web browser that supports most html5 code, and web technologies natively but not AR.
- WeChat has its own app ecosystem that supports mini-apps and mini-games.
- WeChat works best with lightweight experiences; it encourages speed over bandwidth and has data limits.



- WeChat is fully commerce optimised, providing a seamless way for small companies to monetise their services (effectively piggybacking onto the WeChat service). This reduces friction as you are already authorised for micropayments.
- WeChat provides personal details of its users, providing opportunities for some personalisation.

• **Web Development for China**

The concern with developing applications for China is the dependency on server-side resources, as the Chinese Firewall could block them. This affects Web Apps and can impact native applications that read/write to a database or need to load assets on demand. Our research has shown that:

- China only blocks content if it contradicts the country's policies.
- 8th Wall is accessible in China, and they have run multiple campaigns in this region.
- WeChat servers/infrastructure can deploy and run code within China.
- AWS/Heroku-like services are available to deploy internally if required.

• **WeChat Wrappers**

As well as developing modular games, we recommend using wrappers to interface with the supporting frameworks and browsers. In this way, we could develop many of the mini-games using HTML5 canvas but wrap the interface so that the same code works in a normal browser and using the WeChat Mini Game framework.

Our team has successfully implemented this strategy for 8th Wall, allowing the experience to smoothly degrade to a basic 3D application in an unsupported browser. As an added benefit, the user can continue to interact using touch gestures.

• **Technical Evaluation of WeChat Browser**

As part of the project, we also looked at the various technical services, such as available APIs and best practice examples within the WeChat ecosystem. The WeChat in-app browser has the most limited functionality. It does not directly support any AR experience, but there are many benefits for catering to this platform that could add functionality and extend the Web App's user base.

• **Dedicated WeChat APIs**

WeChat has many developer tools and platforms, each with benefits and trade-offs. These include:

1. Official Account
2. Mini Program
3. Mini Game
4. Open Platform
5. WeChat QR Codes

These platforms can be accessed in a variety of ways, through either:

1. Chat messages
2. Web browser hosted within WeChat
3. Web browser external to WeChat
4. Mini Program / Mini Game within WeChat
5. Physical sign-in (scan at entry)

These different experiences can be interconnected in various ways. Interestingly and new for us, the user is adept at switching between them. A recent report on WeChat Statistics suggests that most users in China spend 30% of their time on their mobile phones with the WeChat application (Branka Vuleta, online).

WeChat is not just a social tool – it is also used by professionals for workplace communication; for check-in at hospitals; and to make payments at petrol stations. In other words, it permeates every aspect of the user's life and is an effortless experience with few barriers to entry.

We found in our research that users have multiple interaction points with WeChat that pull them back into the ecosystem. One can think of this as something other than a singular experience; instead, we realised for our project that we can create a modular system that intersects with as many of these interaction points as possible.

The approval process to fully utilise the WeChat platform is essential and needs further exploration as it unlocks some additional features. For example, we would want to use deep links to launch WeChat Mini programs and Chat messages from an external webpage; access to this feature has been locked down in the last few years and is tightly controlled.

There are also reports of some services having developed creative workarounds, such as copying links between apps that are automatically parsed in the secondary app (see, e.g., Ashley Galina Dudarenok, online) and receiving WeChat messages. These message exchanges can include links to web pages that the user can open to access richer functionality.



Official Account

This is the most established developer platform. It is like a Wechat account for businesses, it can send and receive Wechat messages. These message exchanges can include links to web pages that the user can open to access richer functionality.

Typical Use Cases

- **China Merchants Bank Credit Card Centre**

Translation into English: As a cardholder, you can quickly query credit card bills, credit limit and points; quickly make repayments and apply for paying bills by instalments; connect to Customer Service via Weixin; make purchases using a credit card; and receive transaction notifications via Weixin. You can also apply for a credit card via Weixin if you do not have one.



Fig.25: China Merchants Bank Credit Card Centre WeChat messages.

- **China Southern Airlines**

Translation into English: You can check-in, choose a seat, query flight information, and check the weather in the destination city, and you will receive professional services if you are a SkyPearl Club member.

The China Southern Airlines Official Account allows users to link their SkyPearl Club member cards with their Weixin IDs to book flights, check orders, and even check in via the Official Account..



Fig.26: China Southern Airlines WeChat messages.

- **JS-SDK (Java Script-Software Developer Kit)**

For web apps loaded through the WeChat browser, there is the JS-SDK. This is a compact library that allows the web app to login (retrieve user info), customise the share options, select images (camera or gallery), incorporate voice recognition, access location, Shake API (connect to the official account), search local iBeacons, WeChat Pay API. We recommend treating this as a degradable addon to a standard web app; in regular browsers, the WeChat features are ignored, but when hosted in WeChat, additional features are activated to encourage more sharing or to accept micropayments using the WeChat Pay API.

- **QR Codes**

QR codes, a form of matrix barcodes now commonly used also in the West, are the backbone of the WeChat user experience, and users are highly accustomed to scanning them from the WeChat app. This process is highly secure and can incorporate user information and payment; hospitals have implemented it for quick check-in and petrol stations for quick pay at the pump.

QR Codes can be generated using the WeChat API. When a user scans a QR code with a scene value, the following two events may be pushed:

If the user still needs to follow the Official Account, they can follow a link. Weixin will then push the Official Account following the event with the scene value to the developer.

If the user has followed the Official Account, they can scan the QR code to start a chat, and then Weixin will also push the scan event with the scene value to the developer.

- **Mini Program / Mini Games**

WeChat has catered to users with limited mobile data plans by providing very compact and readily accessible mini-apps. These are called Mini Programs and Mini Games and are written using a bespoke framework limited by file size (10Mb) and feature set. However, it is locally cached, has direct access to user information, and can be readily shared.

Mini Programs are particularly challenging to develop as they are limited to WeChat components, and a custom look and feel are difficult to achieve. However, Mini Games share many standard features as games were written for HTML5 Canvas and are accessible; front-end developers will find the library familiar.

Despite the extra effort, there is a lot of appeal in developing Mini Programs. Tencent provides developer support and there is deeper integration with WeChat that can make products and services more viral and accessible. Western brands such as JD.com and Tesla both provide Mini Programs even though they already have established websites and native applications.

JD.com has a vast user base on WeChat and provides a simple keyword search mechanism to find most products. (See: Technode online #01).

Tesla allows users to search nearby Tesla experience halls, charging stations, reserve a Tesla test drive and participate in Tesla's official activities. (See, *Technode*, online #02)

- **Open Platform**

This third-party sign-in is comparable to using Google or Facebook to sign in with standard credentials and grants access to basic user information.

WeChat Strategy

We have argued that it is common practice to use QR Codes in physical locations such as theme parks to provide users with fast check-in or to unlock extra content. This method can also expose users at the theme park or visitor attraction, such as ours, to an online experience and, in doing so, can attract the online audience to the theme park for special content (like *Pokemon*). Furthermore, we can consider the Shake to Follow API to allow users to connect to the Official Account.

The online web app will be the full-fat experience that can be fully experienced in Safari/Chrome but will provide Mini Programs and Games that can be used to complete some of the core tasks. Cut scenes between mini-games and tasks could be an opportunity to push the user back into the full experience, optional but highly rewarding (possibly worth extra credit too).

Microtransactions perform very well in Mini Programs and Games using the WeChat eStore to sell Stickers and custom skins.



iv. Sprint 3: China and technical validation of sharing element

Technical Prototypes: MP 01 and MP 06

This sprint was a case of applying the technical research from Sprint 2 to technical prototyping to validate the sharing and porous approach discussed in Sprint 1.

We took the sharing aspects of the ASDS concept as our example to demonstrate how this might look within a creative narrative, effectively showing how a game experience could be played over time within WeChat and the web. To do so, we created a seamless user journey between the WeChat ecosystem (web browser, mini-apps and mini-games) and the wider web. This created a multitude of entry and exit points. The only technical dependency for using the web was that WeChat does not support WebAR. This meant sending people out of WeChat onto a web platform or offering a non-AR version of the same experience.

The result of this became a point of discussion to decide whether to adapt the technology to the user or to adapt the user to the technology; in case we felt that the advantages offered by AR were compelling enough to encourage users to move out of their current native WeChat experience. The technical prototyping sprint demonstrated the following project ambitions:

1. To take people into and out of WeChat seamlessly.
2. To take interaction elements in one medium and transfer them to another; e.g., allowing someone to make a mark or selection within a native WeChat experience and have that appear within AR in a browser.
3. To offer an alternative version of an experience dependent on if they were in WeChat or on the web.

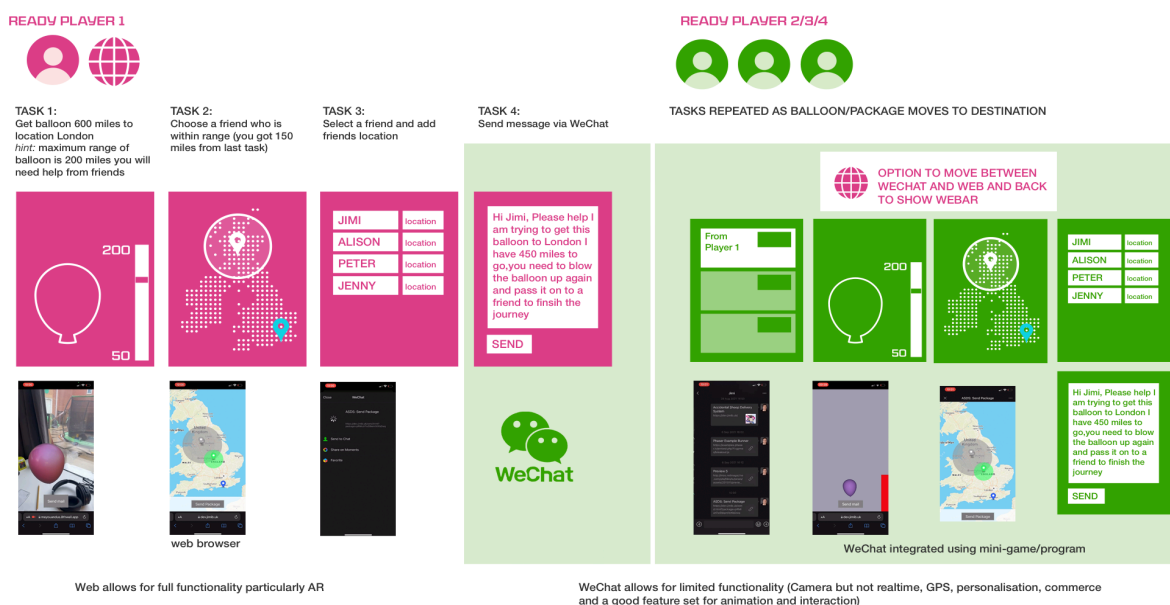


Fig.27: Schematic of the Accidental Sheep Delivery Service concept.

V. Sprint 4: Technical Validation of Game Element

Technical Prototypes: MP 07

This sprint explored the game mechanic approach we discussed in Sprint 1. Our ambition was to create a gaming experience equivalent to a 3D version of the Nintendo Game & Watch handheld consoles of the 1980s. In order to achieve this, we put significant efforts in creating a physics engine that worked in HTML5. Our development team created a rapid framework based on *React Fiber* and *ThreeJS*, which used *CannonJS* for the physics engine.

- **Tools and approaches researched in this sprint**

- Draco (GLTF compression)
- Web Workers (performance boost)
- Ammo / Cannon (various physics engines)
- React Spring - spring-based animation
- Environment reflections - life-like reflections
- Lighting + Shadows
- Physics-based rope

The combination of these tools created a physics engine specifically focused on balloons and tethers. This gave us an accurate simulation of how attaching balloons to increasingly heavier and misshapen parcels would lift them. We also worked on the physics of the ropes to show how they might flex based on the movements and behaviour of the balloons and parcels.

Once the physics system was developed, the final deliverable for this sprint consisted of five low-fidelity game prototypes based on narrative instances, namely “helping launch” or “land a balloon”. All the games were initially presented in a virtual 3D scene before later being converted into a mobile experience using WebAR. As Shaun episodes do not include dialogue, we placed a blackboard in each scene with instructional diagrams.

Another aspect of our prototyping was to take advantage of the mobile devices IMU to physically manipulate the device in space to help control the 3D environment and gameplay as much as possible. Below is a list of technical prototypes of gameplay developed to validate, explore and refine the physical interaction side of our research.

1. The basic game is attaching a balloon to a parcel to lift it and keep it balanced and then progressing to heavier parcels and the need to attach multiple balloons to different parts of the balloons.
2. Users have to place repairs onto holes that are appearing in the balloon to keep it in the air.
3. Users have to land a balloon safely, taking inspiration from the Lunar Lander arcade game (Atari, 1979).
4. The gameplay requires having to land the balloon on a specific target.
5. Users have to use head movements in order to keep a balloon in the air (Shaun heading the balloon), using computer vision.

Hyper-casual games generally describe a simple, easy-to-learn and play games that only rely on minimal user input. Our prototypes proved that the hyper-casual gaming approach worked well in WebAR and also fitted into the brand and universe of Shaun. Combined with the work completed in Sprint 3, it also meant we had validated and answered all the technical challenges behind creating a web-based remote experience like the *Accidental Sheep Delivery Service*.

The Aardman team was now keen to get a sense of the fidelity of WebAR and how their characters could populate and become centre-stage in the project. In response to that, we focused on developing two creative prototypes for the next sprint. One reflects the Shaun world and the other the Chinese world and context, emphasising prototyping the look and feel and pushing the quality of the visuals and animation.

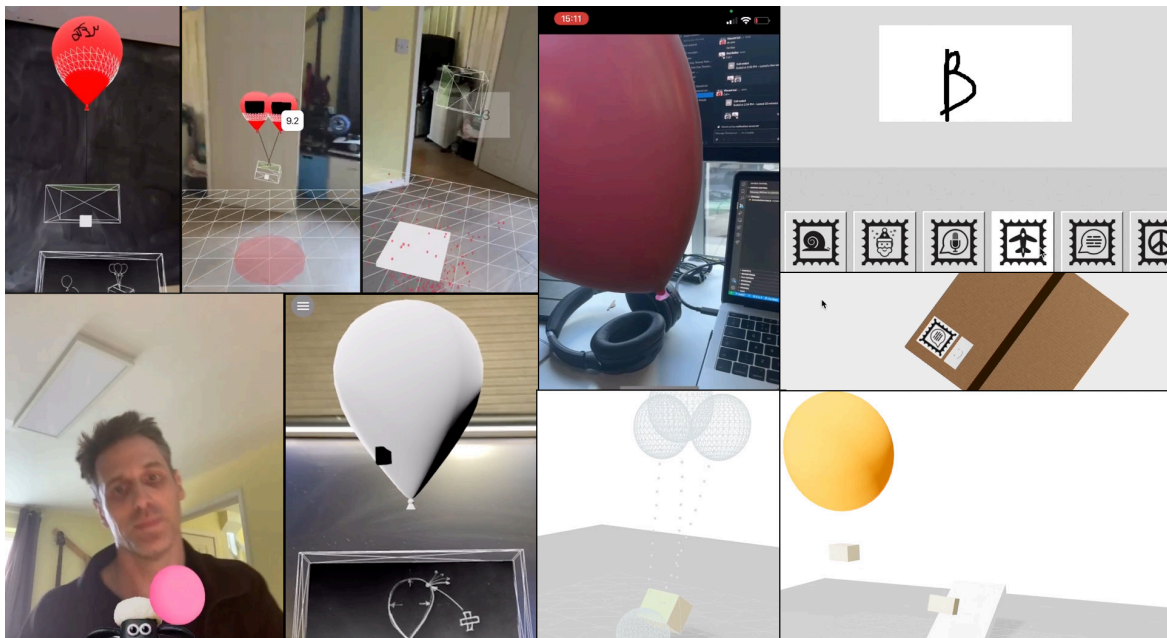


Fig.28: Some of the prototypes developed for Sprint 4.

vi. **Sprint 5: Creative Validation of Game Elements (fidelity & animation)**

Creative prototypes: MP01, MP08, MP10, MP13 and MP14

Typically models in WebAR have a low quality, almost retro console aesthetic. This is because AR requires the realtime creation of digital assets, which is processor intensive. This means that 3D models must be simplified with fewer polygons and simpler shaders and textures.

One of the advantages of using simpler models is that it makes it cheaper to produce WebAR experiences. However, unfortunately, this has given WebAR a reputation for low quality and low-budget projects primarily used for novelty marketing campaigns. We, therefore, wanted to demonstrate, on the other hand, that, by combining innovative thinking and resources, it was possible to create a WebAR experience that was elevated significantly above currently used industry standards for this technology. The following will describe two instances where this was put to a WebAR test.

- **Chinese-based Prototype: The Dragon**

One of the principal Chinese characters from the main, location-based project was a Chinese dragon. The project team therefore felt that using this character would be a good starting point to explore the limits of fidelity and creative expressions. In addition, because a dragon is a character outside the normal Shaun universe, it allowed us the freedom to consider many different creative treatments.

By choosing the dragon, we also discovered further narrative opportunities to make the character part of some of our balloon game prototypes from the earlier sprints. For example, the dragon could use fire to either help keep the balloon in the air or to help it navigate, which led us to create a prototype character that could work with such a narrative option.

In addition to a particular movement pattern, our dragon prototype effectively had two elements – the texture and the modelling – both of which defined the character of the dragon. We researched historical Chinese dragons to look for the use of colour and texture. We found that using red and gold did not just correspond with other cultural precedents, but also worked well within AR. In practice, that meant that we noticed the colours stood out in our testing of real-world environments, which was what the team needed. However, making the gold metallic bold and life-like (as animation) took several iterations.

For the form of the dragon, we looked at placing 2D elements into a 3D world, for example, creating a paper body for the dragon. We then looked at making the body into a 3D tube. One notable approach was when we re-imagined children's wooden dinosaur model kits that are made from assembling a single thin sheet of wood with all the parts cut out. The final result reflected all of these options.



Fig.29: Prototyping the dragon and exploring different texture and animation approaches.

- **Translating an Aardman Character into WebAR: Shaun AR**

This prototype's focus was looking at different animation techniques for Shaun within WebAR. The parent project had been looking at creating a 60fps version of Shaun, so we wanted to take a different approach. Our starting point was looking at how Shaun had been animated and recreated across digital media (AR, VR and 2D gaming). We felt the medium and conventional animation techniques had informed many examples. However, none seemed to reference or be informed by the animation technique used in the TV programs and films.

We were interested in how we could give the WebAR animations an element of the stop-motion technique Aardman is famous for. We identified the frame rate and the unpredictable nature of a human, making tiny adjustments to the model between each frame as an area we could look to replicate.

Our innovation challenge lay in creating an intermediary model of Shaun placed in the pipeline between the animation input (animations created using conventional 3D software) and the animation output that controlled our model of Shaun in WebAR. This intermediary model allowed us to affect the smooth animation data and test techniques that would introduce imperfections and give the model a more human and analogue motion. After various tests, we developed several control types and values that greatly impacted how Shaun moved and behaved. The following actions helped us in our development.

- **Floppy Control:** We added a floppy control to his ears using physics to programmatically alter the amount of flop and wobble when Shaun moved his head to mimic a particular feature of how Shaun is animated.

- **Adjustable frame rates:** We programmed adjustable frame rates for different parts of the Shaun character to reflect how the animators traditionally moved some body parts more frequently than others. For example, Shaun's pupils animate at 4 fps, whereas his head animates at 8 fps.

- **Noise Value:** We experimented with noise value that would interfere with the smooth maths-based motion paths created by the 3D software to make it more analogue and chaotic.

- **Dynamic Positioning.** We worked on dynamically position Shaun's mouth in relation to the position of the camera so that it appears on the side that the user is looking at Shaun.

There was a second reason why we were keen to take and test Shaun 3D models from the parent project in our remote project. We were interested in looking at various optimisation techniques to convert the model of Shaun created for the high-end immersive Unreal gaming engine of the parent project into one optimised for use in WebAR.

We used the standard optimisation techniques of simplifying the model and baking in textures to reduce the file size and the amount of processing involved in displaying the model in WebAR. The main modification and new approach we made during the process were to the texture of the wool. We introduced a more photo-realistic texture and created a feather and bleed where the wool overlaps the body. The result of both the animation and optimisation approaches was a Shaun that felt much closer to the stop-motion Shaun from the TV program than any of the other digitally animated versions we had seen.



Fig.30: Prototyping the fidelity and animation of Shaun including audience interaction.

vii. Sprint 6: Sheep & Greet: Final Creative Prototype

For the final creative prototype, we were inspired by observing human behaviour during an in-person team workshop at Aardman studios in Bristol. One of the key moments was when we demonstrated our augmented Shaun. Naturally, everyone in the team wanted to take a selfie with him. This, however, proved to be from a technical point of view a rather clunky and complicated process. Instead of following the selfie approach, we came up with the idea to designate one person as the photographer, who could also instruct the participants to position themselves with Shaun. This allowed us to formulate a new game.

In the days after the workshop, we came up with the idea of Sheep & Greet to create a WebAR experience focused on making having your picture taken with Shaun fun and interactive. The starting point was our WebAR Shaun that we built in the previous sprint. In addition, we introduced face detection and skeleton tracking to enable Shaun to interact with the user. As a special interactive feature of the prototype, we programmed Shaun in such a way that he would mimic the participant's movements.



Fig.31: Professor's Koeck and Pan providing inspiration for final prototype.



Fig.32: Final Prototype concept.

viii. Reflections of the Development of a Remote Experience

It is interesting to reflect on how the project changed and how the original aims remained consistent throughout the 18-month duration. Having a research project with the delivery of a prototype rather than a commercial product allowed us to focus on outcomes and learning that evolved through the process. In addition, it enabled our team to cover a lot of ground and create a lot of varied technical and creative prototypes.

At a high level, this project was about combining three challenges, technical, creative and geographic. First, we wanted to validate and answer the question. How can you make a Shaun the Sheep experience for mobile phones with mass audience appeal within the Chinese market? We interpreted this to be how can you make a web-based Shaun experience that is intrinsically shareable and driven by an addictive hyper-casual gameplay and which also considers the Chinese cultural context. By formulating a series of sub-research questions, we aimed to see how far we can push the fidelity and complexity of WebAR.

We started with a list of rational requirements around sharing and interaction and then applied to a newly developed narrative, and creative concept – our Accidental Sheep Delivery Service – to articulate those requirements within a creative framework. The first half of the project was spent validating those requirements through research and developing technical prototypes. At the end of this process, we spent the other half of the project expanding on the more creative aspects by prioritising the interactive elements. This resulted in sprints 4, 5 and 6 following a process of increasing refinement and fidelity till we ended with our final prototype – Sheep & Greet.

The Accidental Sheep Delivery Service proved to be an enduring concept that all of the prototypes could have been part of while being valuable as a standalone experience or part of a completely different overall concept. This is one of the key learnings the team at FeedAR will take forward. Having a creative concept to test and validate technical requirements is an interesting approach. It effectively kills two birds with one stone. It allows for the validation of individual research questions whilst, in the end, offering a fully tested and validated creative concept. One that could be taken forward into production with a significantly reduced risk and much of the groundwork completed.

While our final prototype Sheep & Greet can be used as a concept and gameplay in its own right, it could also easily form part of several moments within the ASDS experience. For example, it could be used for a player to share that he/she had completed the task of getting the gift to the recipient. Alternatively, it could be used to share your experience or recruit friends to help with the task.

The other key learning is how WebAR does offer fidelity and complexity to compete with a native experience. Although the primary reason for choosing WebAR is to remove the need to install an app and to work in a Chinese Market, there are several other benefits. In the context of this research, it gave us the ability to make a game experience porous and to live across different channels and timelines – both points that have become extremely important during the process.



VII. Spatial Sound

i. The Role of Sound in an Immersive Environment

From an architectural and film perspective, the sound is often neglected in the design of projects. Our 'investigations into the sonic quality of spaces lag behind the vast amount of visual studies of cities which either focus on mediated, two-dimensional spaces (in photography or movies) or as three-dimensional phenomena' (Koeck 2013: 106). Sound is an important carrier of spatial information, and reaches into our emotional disposition towards the spaces we encounter in our everyday lives. (ibid., 106). Our conscious perception tends to focus on the visual, meaning that we are

often unaware of how much sound is an active carrier of qualitative and spatial information, providing us important clues in terms of the environment in which we are in. Much more could be expanded here, but in terms of our specific case – and this being a very interdisciplinary project and team – we recognised that when dealing with the design of an immersive, theatrical environment, we needed to give sound and sound design as much attention as other elements in our project. For the Shaun Immersive Experience, sound plays multiple important roles.

ii. Spatial Sound Settings and Materials:

Shaun Immersive Experience plays out a story that takes place in several spatial settings in which an audience would be immersed. We believe that sound and sound design will give the audience a greater understanding of the spaces in which they are in, including their differences (e.g., open or closed; interior or exterior). This being an entirely digitally created environment, we see in sound and sound design a good opportunity to also highlight material properties; audio responding to for instance physics and touch (e.g., soft bouncing; hard reverberating). Much of this, of course, is the knowledge that Aardman, with its ample experience in moving image productions, would already be very aware of. Our particular challenge here, however, was to translate that awareness and knowledge into an immersive experience and a physical, theatrical setting, and highlighting the fact that sound could be received by the audience directionally and spatially.

- **Audience Orientation:**

Since our project allows for a physical audience experience – one in which there are not only multiple screens, but also potentially a mobile audience – we realised that special attention needed to be given to the audience being able to orientate themselves in such an immersive space. Unlike in the cinema, where an audience has more or less a fixed position that comes with a clear understanding of where to look, in our theatrical setting the relationship between audience and screens is more dynamic. We recognised that multiple on-screen content can only immerse an audience, but also has the potential to distract or disorientate people in the space. This has not only narrative implications, which will be discussed in the next section, but the audience's ability to orient themselves is also relevant from an operational and health and safety point of view. With 50 or more people occupying a dark space, where they might or might not have a clear sight on screens, sound can be used as a tool to direct people to a particular place, such as an exit.

- **Storytelling:**

As we know from VR films and games, being immersed in an environment, where one can freely choose where to look at, comes with some caveats. As soon as we leave the cinematic mode, that is having an audience's attention focused on one screen and frame, storytelling can become a challenge. Handling 'multi-user storytelling environments in virtual reality' raises questions about the 'handling story progression and maintaining user presence' that need to be further investigated (Brown et al. 2017). We agreed from the beginning that the Shaun Immersive Experience

would need to be story-, instead of tech-driven. That produced for us a high bar and difficulties which we tried to mitigate in several ways; one of which was through the use of spatial sound. We believe that immersive experiences, such as ours, would need to pay attention to sound and use it as an active story element. We conceived spatial sound as a way to direct the audiences' attention towards, for instance, a particular screen, character or critical action, so that a narrative flow could be maintained.

The Application of Spatial Sound in Realtime Environments

The massive growth in the games industry in recent years has led to realtime games engines, such as *Unity/Unreal Engine*, evolving in a way which has opened up the ability for developers to access specialised tools created specifically to immerse the gamer in the game through haptic and olfactory feedback, kinetic energy (hot/cold); all of which are what we would call one way signals, which support our sense of immersion by encouraging the gamer to trust what they experience.

Spatial sound, on the other hand, has also seen some real development in recent years, which is often applied to games design. The current state of the art in audio technology allows sound to be produced in such a way that listeners can get a sense of both the direction and distance of sound. When this sound is binaurally reproduced in appropriate headphones and linked to a full 360 degree tracking of the stationary gamers head, it gives a convincing immersive sound experience, which arguably significantly increases a sense of spatial and story immersion. In

Our project, however, we had to consider alternatives to the use of headsets, yet reproducing similar immersive effects.

In meetings between Aardman and CAVA teams, we quickly realised that headphones would not be a practical solution for our physical experience and that another solution would have to be developed. We did not like the idea that visitors to our family experience would be required to wear any audio headsets. For the system we had in mind for our physical experience, the immersive spatial sound quality could not be delivered through tracked headphones, but had to be headphone and tracking free. This required us to rethink and redesign the space. We concluded, in consultation with the Shanghai Theatre Academy (who were planning and building the XR test space that we gave our advice on), that we needed to design a bespoke speaker array for our physical immersive experience.

Unreal Engine is currently capable of delivering first-order ambisonics out of the box but with specialised sound rendering

middleware development the *Unreal Engine* scene is capable of outputting second and third-order ambisonic sound through a pre-configured speaker array. During the live performance, *Unreal Engine* drives the middleware which in turn converts character sounds to a format suitable to be played through the speakers into the physical space.

Using a speaker array has the potential to transform the audience experience considerably, but it also has other advantages over the use of headphones. The team discovered that when wearing headphones during an immersive production experience, immersion is heavily disrupted if the user pushes a button to move through the virtual space, without moving in their physical space. A physical speaker array set up to deliver spatial sound through the games engine, on the other hand, will allow the audience to move physically and experience the change in sound in a more natural way,

reducing the feeling of disorientation and increasing trust in the story.

Our experience is envisioned for an audience to share and interact with the physical space. Working with a speaker array would remove the issue of the personal bubble effect, created when using headphones, as our audience would find one-to-one or conversation between groups likely to be difficult if they would wear headphones. This pointed us to the conclusion that speaker arrays have a unique way of bringing an audience together during a shared experience, similar to the effect experienced when attending a live stage show. In our specific auditorium space, with an assumed dimension of 15m x 15m x 5m, we decided to recommend a 27.1 spatial sound hemispherical speaker array, with a sound system capable of delivering spatial sounds simulated by the *Unreal Engine* and additional associated middleware.



VIII. Outcomes

Above and beyond what this report has sketched out, this R&D project resulted in a number of positive outcomes which we hope will be further amplified in the future. First of all, Shaun the Sheep: Immersive Experience allowed us to form a new, highly interdisciplinary and diverse project team which will hopefully continue to collaborate in the future. It consisted of two major UK universities – the University of Liverpool and Goldsmith – who brought complementary expertise to the project spanning from architectural design, with an emphasis on immersive design and computer science, with an emphasis on virtual reality. Furthermore, it allowed us to work with a highly motivated and supportive team of the Shanghai Theatre Academy (STA), who contributed to the project with their knowledge of the cultural context, animation and immersive technology. One of the side benefits of this collaboration was that we could help our STA partners to build a state-of-the-art XR lab at their new campus. Last but not least, this academic partnership benefited immensely from working with a globally leading creative industry partner, Aardman. In practice, this meant that the project benefited not only from working with a recognisable brand, but also and quite concretely from working with a large team of experts that spanned well beyond our initial scope and expectations. The Aardman team working on this project provided invaluable expertise and leadership in project management, storytelling, digital production, as well as commercialisation. In turn, this close collaboration with our industry partner allowed us to carefully listen and subsequently respond to professional expertise or market demands. Since it was beyond the scope and reach of this R&D project to deliver a final, polished

product, we indeed allowed ourselves to explore, reach limits and occasionally fail in coming up with single answers to inter-connected problems. Yet, this has also been the strength of the project and framework under which the AHRC allowed us to work collaboratively. The strength of this project lies perhaps in having looked at so many aspects, thereby demonstrating the dependencies and interconnectedness of decision-making, resulting in a quite comprehensive understanding of what would amount to a highly attractive immersive visitor attraction. And last but not least, we believe that this AHRC project will have a lasting impact on Aardman. We have seen already that Shaun the Sheep: Immersive Experience has led to a change of culture inside Aardman. Our project helped to introduce the possibility of more digital and hybrid dissemination channels for Aardman's animation products as well the incorporation of realtime, game-engine-driven, technologies for content production which nevertheless, truly carry the Aardman signature craftsmanship, humour and wide public appeal.

Arguably the most opportunity for overt audience interactions would occur during the immersive show in the auditorium. The advantage of this space is that the auditorium is a controlled environment, with a clear entrance and exit, and designed in such a way that the audience would be encouraged to position themselves in a particular way. All of this helps when dealing with sensors and algorithms that are trying to gather and interpret data. Having this said, there is another side to this. Being an audience member inside an immersive theatre is a perceptual act. The challenge in terms of the design of an interaction scenario is therefore not

so much a mechanical or technical one – with enough budget all kinds of interactive effects could be created. Instead, we recognised the importance that the overall immersive and indeed the story experience needs to remain uninterrupted. This could almost be seen from a film language point of view. Much like a continuity edit in film, within an immersive story space, one has to find an interaction language that protects and preserves the spatio-temporal and narrative unity of the experience.

During the course of this development, we became also aware that the realisation of an interaction scenario is not only a technical question. Instead, in our case

quite particularly as it was designed for a Chinese audience, it became a problem that needed solving which was filled with cultural implications and unknowns. This can be illustrated with an unrefined example. How, for instance, would a Chinese audience member react if that person would be singled out and asked to interact with an on-screen character in front of an audience? This demonstrates also to think carefully about the types of interaction scenarios one would want to develop in such a setting, for instance, if it would be an individual or group interaction.



Presentations

UK Research and Innovation China (2023, March), Exhibition at 'Bridging Creativity: Celebrating UK-China Collaboration in Arts & Innovation', Hellas House in Shanghai.

Eilbeck, A. (2023, March), Seminar of 'Shaun the Sheep Remote Experience', Shanghai Theatre Academy, Shanghai.

AHRC Symposia (2023, March). 'Crafting Immersive Experiences for Future Global Audiences', hosted by Koeck and Pan with presentations of the project team and Aardman. Fora, London.

Hilton, C., Pan, X., Koeck, R., & Yu, H. (2023, March). Simulating Location-Based Experiences in VR. In 2023 IEEE Conference on Virtual Reality and 3D User Interfaces Abstracts and Workshops (VRW) (pp. 119-122). IEEE.

Hilton, C., Pan, X., Koeck, R., & Yu, H. (2023, March). Prototyping Large Scale Projection Based Experiences in VR. In 2023 IEEE Conference on Virtual Reality and 3D User Interfaces Abstracts and Workshops (VRW) (pp. 1005-1006). IEEE.

Aardman Workshop (2022, July), 'Remote Experience', presentation by entire project team, hosted by Aardman in Bristol.

AHRC VR & Machine Learning workshop (2021, September). Hosted by R. Koeck, University of Liverpool with presentations by Pan, X and Gillies, M and members of the Digital Innovation Factory, University of Liverpool.

Koeck R., (2021, March). 'History and Future of Immersive Experiences: ground-breaking innovations and spectacular failures', public online lecture (over 500 people signed up), hosted by the School of the Arts, University of Liverpool.

Koeck, R., Guo, M., Harding-Hill, N. (2020, December), 'Shaun the Sheep in Shanghai', Beyond Conference, supported by UKRI.

Koeck R. (2020, November), 'Shaun the Sheep: Immersive Experience', New Media Performance Innovation: International Expert Workshop, hosted by Shanghai Theatre Academy



References

- Adrian, J., Seyfried, A. and Sieben, A., 2020. Crowds in front of bottlenecks at entrances from the perspective of physics and social psychology. *Journal of the Royal Society Interface*, 17(165).
- Atkinson, S., 2014. *Beyond the Screen: Emerging Cinema and Engaging Audiences*. Bloomsbury Publishing USA.
- Bradski, G., 2000. The openCV library. *Dr. Dobb's Journal: Software Tools for the Professional Programmer*, 25(11), pp.120-123.
- Brown, T., 2013. *Breaking the Fourth Wall*. Edinburgh University Press.
- Brown, C., Bhutra, G., Suhail, M., Xu, Q. and Ragan, E. D. 'Coordinating attention and cooperation in multi-user virtual reality narratives,' *2017 IEEE Virtual Reality (VR)*, Los Angeles, CA, USA, 2017, pp. 377-78.
- Furnham, A., Treglown, L. and Horne, G., 2020. The Psychology of Queuing, *Psychology*, 11(3).
- Hanich, J., 2017. Audience effect: On the collective cinema experience. Edinburgh University Press.
- Kelly, K., 2016, *The Inevitable: Understanding the 12 Technological Forces that will shape our Future*, NY Viking Press.
- Koeck, R., 2013, *CineScapes: Cinematic Spaces in Architecture and Cities*. London/ NY Routledge.
- Liu, Y., 2018. Social Media Marketing in China mit WeChat. *Fachmedien Wiesbaden*, Springer.
- Martínez, M.A., 2014. Storyworld possible selves and the phenomenon of narrative immersion: Testing a new theoretical construct. *Narrative*, 22(1), pp.110-131.
- Maister, D.H., 1984. *The Psychology of Waiting Lines*, Boston, Harvard Business School, Background Note 684-064, pp. 71-78.
- Olson, Greta, ed., 2011. *Current Trends in Narratology*. Berlin, De Gruyter.
- Xu, W., 2017. The study of WeChat payment users willingness factor. *Journal of Service Science and Management*, 10 (3), pp.251-259.
- Sosa-León, V. A. L. and Schwering, A., 'Evaluating Automatic Body Orientation Detection for Indoor Location from Skeleton Tracking Data to Detect Socially Occupied Spaces Using the Kinect v2, Azure Kinect and Zed 2i', *Sensors*, vol. 22, no. 10, p. 3798, May 2022, doi: 10.3390/s22103798.
- Jacob, R. J. K. et al., 'Reality-based interaction: a framework for post-WIMP interfaces', in *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, Florence Italy: ACM, Apr. 2008, pp. 201–210. doi: 10.1145/1357054.1357089.
- Slater, M. 'Place illusion and plausibility can lead to realistic behaviour in immersive virtual environments', *Philos. Trans. R. Soc. B Biol. Sci.*, vol. 364, no. 1535, pp. 3549–3557, Dec. 2009, doi: 10.1098/rstb.2009.0138.

Hilton, C. et al., 'InteractML: Making machine learning accessible for creative practitioners working with movement interaction in immersive media', in Proceedings of the 27th ACM Symposium on Virtual Reality Software and Technology, in VRST '21. New York, NY, USA: Association for Computing Machinery, Dec. 2021, pp. 1–10. doi: 10.1145/3489849.3489879.

Yu, F.-H., Chen, K.-Y. and Lu, K.-H, 'Non-Autoregressive ASR Modeling Using Pre-Trained Language Models for Chinese Speech Recognition', IEEE/ACM Trans. Audio Speech Lang. Process., vol. 30, pp. 1474–1482, 2022, doi: 10.1109/TASLP.2022.3166400.

Monteiro, P., Gonçalves, G., Coelho, H., Melo, M. and Bessa, M., 'Hands-free interaction in immersive virtual reality: A systematic review', IEEE Trans. Vis. Comput. Graph., vol. 27, no. 5, pp. 2702–2713, May 2021, doi: 10.1109/TVCG.2021.3067687.

Khalil, R. A., Jones, E., Babar, M. I., Jan, T., Zafar, M. H. and Alhussain, T., 'Speech Emotion Recognition Using Deep Learning Techniques: A Review', IEEE Access, vol. 7, pp. 117327–117345, 2019, doi: 10.1109/ACCESS.2019.2936124.

Lee, M.-C., Yeh, S.-C., Chang, J.-W. and Chen, Z.-Y., 'Research on Chinese Speech Emotion Recognition Based on Deep Neural Network and Acoustic Features', Sensors, vol. 22, no. 13, Art. no. 13, Jan. 2022, doi: 10.3390/s22134744.

Online sources

Vuleta B (2023) last accessed from <https://99firms.com/blog/wechat-statistics/#gref>

Dudarenok A G (2018, May 23) (2023) last accessed from <https://jingdaily.com/external-links-wechat/>

Technode (2018, June 14) (2022) last accessed from: <https://technode.com/2018/06/14/wechat-jd-shopping/>

Technode (2022) last accessed from <http://www.wxgmkt.com/en/case-detail/co/61/>

