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VIRTUAL AVEBURY: EXPLORING SENSE OF PLACE IN A VIRTUAL ARCHAEOLOGY SIMULATION

AVEBURY VIRTUAL: EXPORACIÓN DEL SENTIDO DE LUGAR EN UNA SIMULACIÓN ARQUEOLÓGICA VIRTUAL

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Highlights

- More than 1200 members of the public experienced a 3D, fully immersive simulation of Avebury Henge, Wiltshire, UK over a nine-month period.
- We found patterns of use and familiarity with information technology (IT), and using mobile technologies for gaming, that did not follow age and gender stereotypes.
- We found little correlation between age, gender and IT familiarity with reactions to Virtual Avebury, suggesting that such simulations might have wide appeal for heritage site visitors.

Abstract

This paper describes and discusses creating and evaluating a virtual reality simulation of Avebury Stone Circle and Henge complex as it might have appeared and sounded circa 2300 BCE. Avebury is a Neolithic heritage site in the UK which is part of the Stonehenge, Avebury and Associated Sites UNESCO World Heritage Site. The overall aim of the project was to better understand the sense of place and presence that visitors can experience in virtual simulations of heritage sites. We investigated how virtual spaces might become experienced as places by visitors through their exploration, active participation, sensory stimulation and communication with other visitors in the simulation. More than 1200 members of the public experienced the simulation, both at Avebury itself and at three public exhibitions. The specific objectives of the project were to explore if and how the believability of a simulation was associated with feeling a sense of place in the virtual landscape, and if some personal characteristics, viz. age, disability, sex, immersive tendency, familiarity with IT and frequency of playing computer games, were associated with levels of enjoyment in, and learning from, the simulation. We analysed the data from a detailed questionnaire completed by 388 of the 702 visitors to Avebury from June to September 2018 who experienced the simulation, supported by observational data from all participants at all events. We found that believability was associated with a sense of place in the simulation, i.e. that the more believable the simulation appeared, the greater the sense of place experienced by the participants. We also found that personal characteristics had very little influence upon visitor reactions to the simulation, suggesting that such simulations might have wide appeal for heritage and museum visitors, regardless of age, gender or familiarity with technology.

Keywords: public engagement in heritage; sense of place; virtual reality (VR); henge monuments

Resumen

Este artículo describe y analiza la creación y evaluación de una simulación de realidad virtual del círculo de piedra de Avebury y el complejo de Henge, ya que podría haber aparecido y sonado alrededor del año 2300 a. C. Avebury es un sitio neolítico patrimonial en el Reino Unido que forma parte de Stonehenge, Avebury y sitios asociados Patrimonio de la Humanidad de la UNESCO. El objetivo general del proyecto era comprender mejor la sensación de lugar y presencia que los visitantes pueden experimentar en simulaciones virtuales de sitios patrimoniales. Investigamos cómo los visitantes pueden experimentar los espacios virtuales como lugares a través de su exploración, participación activa, estimulación sensorial y comunicación con otros visitantes en la simulación. Más de 1200 miembros del público experimentaron la simulación, tanto en Avebury como en tres exhibiciones públicas. Los objetivos específicos del proyecto eran explorar si la credibilidad de una simulación se asociaba con la sensación de lugar en el paisaje virtual, y si algunas características personales, a saber, la edad, la discapacidad, el sexo, la tendencia inmersiva, la familiaridad

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con la informática y la frecuencia de los juegos de computadora se asociaron con niveles de disfrute y aprendizaje de la simulación. Analizamos los datos de un cuestionario detallado completado por 388 de los 702 visitantes a Avebury de junio a septiembre de 2018 que experimentaron la simulación, respaldados por datos de observación de todos los participantes en todos los eventos. Descubrimos que la credibilidad estaba asociada con un sentido de lugar en la simulación, es decir, cuanto más creíble era la simulación, mayor era la sensación de lugar experimentada por los participantes. También descubrimos que las características personales tenían muy poca influencia sobre las reacciones de los visitantes a la simulación, lo que sugiere que tales simulaciones podrían tener un gran atractivo para los visitantes del patrimonio y del museo, independientemente de su edad, género o familiaridad con la tecnología.

Palabras clave: participación pública en el patrimonio; sentido del lugar; realidad virtual (RV), monumentos de círculo de piedra

1. Introduction

This paper describes and discusses a research and development project in which we created and evaluated an immersive, 3D, virtual reality (VR) simulation of a UK ancient monument, i.e. the Avebury Stone Circle and Henge complex, which we called Virtual Avebury (VA). The focus of the project was on creating, exploring and understanding virtual spaces that simulate how a heritage site might have appeared and sounded at a distant period of time, to better understand the sense of place and presence that visitors can experience in virtual simulations of heritage sites. We investigated how virtual spaces might become experienced as places by visitors through their exploration, active participation, sensory stimulation and communication with other visitors in the simulation. Our specific objectives were:

- to explore if believability of a simulation was associated with feeling a sense of place in a virtual heritage landscape, and
- the extent to which age, disability, sex, immersive tendency, familiarity with IT and frequency of playing computer games, affected participants' experiences in the simulation.

We investigated these issues through developing VA as a simulation of the Avebury complex as it may have appeared circa 2300 BCE, and making this simulation available to visitors to Avebury over a 3-month period in the summer of 2018, and to a wider audience at shows and exhibitions in June and October 2018 and March 2019. We assembled a team of researchers and external partners in these fields, viz: archaeology and VR researchers at Bournemouth University, archaeology and heritage specialists at The National Trust, VR developers at Daden Limited, specialists in creating virtual environments and immersive experiences, and sound specialists at Satsymph LLP, a consortium of specialists in interpreting ancient landscapes through sound and voice.

The introductory section below describes Avebury and discusses the rationale for this site being the subject of the study, and then goes on to discuss some of the issues to be considered when using VR in heritage settings. The materials and methods used in the study are then explained, followed by the results of the data analysis and conclusions regarding the findings of the study.

1.1. Why Avebury?

The Avebury Stone Circle and Henge complex is situated in Wiltshire in the South West of the UK (51^{0}25' N, 1^{0}51' W). It is the largest known prehistoric stone circle in the world, one of the largest known henge monuments in the UK and is the northernmost part of the Stonehenge, Avebury and Associated Sites UNESCO World Heritage Site. Its construction is estimated to have taken place in phases spanning the Late Neolithic and Early Bronze Ages, circa 2800-2000 BCE, although detailed dating of construction phases is unclear (Pollard & Cleal, 2004). The roughly circular earthwork is a henge construction, i.e. a ditch on the inside of the circle and a bank on the outside, measuring more than a kilometre in circumference. It is broken into four quadrants by interruptions in the ditch and bank system, interpreted as a means of access to and from the inside of the henge (Pollard & Reynolds, 2002). The ditches and banks enclosed 3 monumental sarsens (silicified sandstone) stone circles. These comprised one outer circle around the inside of the ditch, which contained approximately 100 stones, and at least a further 100 stones that constituted 2 inner circles surrounding specific arrangements of large and small stones at their centres, together with some outlying single stones within the large circle. Figure 1 shows how VA represented Avebury as it may have appeared circa 2300 BCE.

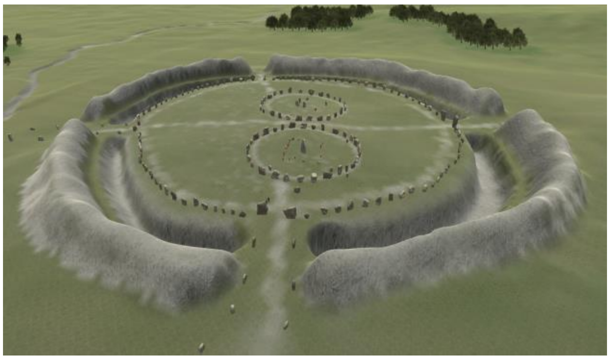

Figure 1: Virtual Avebury, showing the currently understood arrangement of stones circa 2300 BCE.

At Avebury today, the depths of the ditches and the heights of the banks are still striking in some parts (Fig. 2), with the ditches reaching 4-5 m deep and some of the banks standing 4-6 m high. When first dug, the ditches had vertical sides and were approximately 10 m deep, possibly reaching 14 m deep adjacent to the entrances. The banks were likely to have been approximately 6-8 m high and, built from the chalk rock spoil of the ditches, would have been a bright white feature in the landscape when first constructed (Pollard & Reynolds, 2002).

Two avenues lead from the henge, originally marked by standing stones along at least part of their lengths. These avenues were approximately 1.5-2 km long and led to other monuments such as the site of a wood and stone circle (The Sanctuary), making the henge part of a much larger ritual landscape.

Figure 2: Example of a ditch and bank at Avebury today.

The aerial photograph of Avebury today (Fig. 3) illustrates how the monument now has part of the village of Avebury located within it and that most of the original stones are missing. The Avebury monument attracts more than 300000 visitors annually but can be somewhat incongruous and hard to visualise, as it is so large and has been cut through by roads and obscured by later buildings. This makes Avebury a particularly fitting location for investigating how experiencing a virtual interpretation of an ancient monument, free of present-day context, might affect our understanding and interpretation of it today.

Figure 3: Tilted aerial view of Avebury today taken with wide angle drone camera.

1.2. Virtual simulations in heritage management

Ancient monuments are remnants of a distant past that can now appear out of context, abandoned or visible only as elusive marks in the landscape. Some are now wholly or partly obscured through re-shaping of the land due to agriculture or building, or have collapsed, worn away or been deliberately removed as resources for subsequent re-use. Virtual simulations can help to illuminate these decontextualized and obscured heritage sites by illustrating what is now imperceptible and contextualising what is now isolated and incongruous.

Virtual simulations of ancient places are essentially types of reconstructed space, which draw upon aspects of tangible space in the present and imagined space in the past. But they are not just reconstructed space; they can also become recognised as places in their own right. Research into the distinction between 'space' and 'place' has given rise to a rich literature for more than 40 years, which explores that distinction from a range of subject perspectives (e.g. Tuan, 1979; Relph, 2008, Turner, Turner & Burrows 2013). For example, Crane (2016, 15), in his discussion of the development of the British Isles landscape after the last Ice Age, argues that humans have a predisposition to invest locations with emotional attachments, which in turn brings about a sense of place. Fouberg, Murphy & Blij (2020: 11) quote the noted geographer Yi-Fu Tuan to summarise this in three words: "people make places". Regarding the notion of place in a virtual space, Falconer & Scott (2018) and Hampel (2019), for example, provide evidence from studies that show how virtual spaces can become places, recognised and understood as such by people who interact with those places and with other people in them. A virtual space is not simply a surrogate for a physical space; a virtual space can become a virtual place in its own right (see, for example, Scarles and Lester, 2013; Gil-Ortega and Falconer, 2015; Davis and Calitz, 2016).

Simulations of ancient sites need to be constructed and deployed with care, though. Even before the widespread use of virtual technologies, Shanks and Tilley (1992, 84) questioned the use of physical archaeological reconstructions as a means of interpreting archaeological sites. They had reservations about the use of reconstructions for public consumption, suggesting that these attempts at reconstruction risk depicting the past as a fantasy world, clouded by myth and nostalgia. In discussing 3D virtual replicas and simulations of the past, Galeazzi (2018: 268) asks if such replicas are "… original digital representations of our cultural heritage, or just virtual 'fakes'". We discuss these issues throughout this paper, drawing upon our findings, particularly with respect to believability and sense of place that users of such simulations might experience. In this project, VA was described as a simulation, not a reconstruction, to all participants, precisely because it was not an attempt to construct something that once existed in a known form. The focus of this study was not upon attempting to create a replica of Avebury at a particular point in the past, but to construct a plausible retrospective interpretation that draws on the main features of the site that remain today.

As the use of virtual technologies in heritage management began to increase in the first few years of the 21st century, many commentators expressed concern regarding the dangers of hyper-realism, of constructions being based upon unclear evidence and the lack of an agreed protocol for demonstrating intellectual transparency in the design, construction and use of virtual constructions. For example, these concerns are discussed by Earl and Wheatley (2002) in their paper describing a virtual reconstruction of Avebury using a modelling language (VRML) to construct three different interpretations of the southern entrance to the henge. In particular, they comment upon the dangers of over-enthusiasm on the part of constructors of virtual simulations that may lead to constructions espousing a sense of authenticity, rather than interpretation. Concerns such as these led to the development of The London Charter for the Computer-Based Visualisation of Cultural Heritage, conceived in 2006 (London, 2009), which is now recognised as one of the *de facto* benchmarks to which heritage visualization processes and outputs should be held accountable. The objectives of The London Charter are to provide a benchmark for the use of visualisation techniques, promote academic rigour in the processes of planning and construction, promote the use of effective methods for evaluating the outcomes of projects, encourage effective dissemination of the findings of evaluations and ensure the longevity and sustainability of project outputs. The objectives of this project followed both the spirit and requirements of the London Charter and this is discussed in context at appropriate points throughout this paper.

2. Materials and methods

2.1. Creating the simulation

The project aimed "to provide a benchmark for the use of visualisation techniques" (London, 2009) by developing a simulation that could be experienced as a fully immersive, visual, auditory and shared experience for visitors using 3D headsets and haptic (touch) devices. The project objectives were achieved by creating and evaluating VA, a multiuser simulation built on the Fieldscapes™ platform, which is an application built in the game engine Unity 3D. The terrain was built using Terrain Builder v. 1 (open source), based upon the present-day Environment Agency LIDAR data for the Avebury area, which was then adapted to reflect the likely topography for 2300 BCE.

Three-dimensional (3D) mesh models of stones that are currently standing in the henge, together with artefacts and avatars, were created and exported in Collada (.DAE) format, a publicly available specification (ISO/PAS17506). The stones which no longer exist at Avebury were synthesised from the known stones. Many stones have been removed in the 4000 years since construction ceased at Avebury, and it is not possible to accurately know the actual arrangement of the stones at any particular time in its history. To "promote academic rigour in the processes of planning and construction" (London, 2009) the simulation was based upon a range of sources, including early reports of antiquarians such as William Stukeley published in 1743 (Mortimer, 2014) when more of the stones were present, later excavations carried out by Alexander Keiller in the 1930s (Smith, 1965) and modern-day geophysics results (e.g. results reported in Gillings, Pollard & Strutt, 2019).

During March and April 2018, Satsymph captured sounds from the natural environment, including human activity and distant human speech where the language being spoken was not detectable. Other sounds such as animal calls (e.g. kite, deer, wolf and bear) were licensed from commercial audio libraries. These sounds were layered to form a spatialised soundscape that changed as visitors explored the simulation.

Appropriate 3D props, including Late Neolithic (Grooved Ware) and Early Bronze-Age (Beaker) pottery and red deer antler picks, were created and scattered at points in the simulation such as the bottoms of some ditches. These formed a focus for exploration and a rudimentary 'find the pottery and picks' game for younger participants.

Two adult avatars (1x♂ and 1x♀) were created, wearing simulations of Late Neolithic clothing. Participants using the simulation used logins that generated these avatars as their presence and means of exploration in the simulation. When two participants were in the simulation at the same time, they could see each other and communicate through speech or text. There were also two static non-player characters made from the same models, which were stationed near the southern entrance to VA as devices to help participants judge the scale of the simulation.

All parts of VA were finally assembled and tested during May 2018 for the public participation and evaluation phase of the project that began the following month.

2.2. Public participation and evaluation

To "promote the use of effective methods for evaluating the outcomes of projects" (London, 2009) we gathered data from a detailed questionnaire completed by a 55% (388/702) sample of visitors to Avebury over the evaluation period. The simulation was available for public engagement using 3D Oculus Rift headsets and hand-held haptic devices on 45 days from June–September 2018, in the Barn Gallery of the Alexander Keiller Museum at Avebury (Fig. 4).

Figure 4: Participants in the simulation together at The Barn Gallery, Avebury.

We also exhibited at two public events hosted by Bournemouth University (The Festival of Learning in June 2018 and Bournemouth FX in October 2018) and were then invited to take part in a London Science Museum "Lates" event in March 2019. A further 600 people experienced VA at these events. At all events, participants' attention was drawn to the banners next to the simulation, explaining that this simulation was not a representation of how Avebury actually was at any point in time, but a simulation exploring aspects of how it might have been. The reactions, actions, conversations and questions of all participants formed the body of observational data collected by the research team.

For the purposes of this report, we focus upon the quantitative and qualitative findings from the detailed questionnaire feedback we received from the sample of participants at the Barn Gallery in Avebury, who completed the questionnaire immediately after they had experienced VA. We use the observational data from all participants to give further context to the findings from the questionnaire element of the research. In the questionnaire we collected age, gender, disability and nationality demographic data, and responses to questions relating to participants':

- current use of IT,
- frequency of using IT for playing computer games and similar purposes, including previous use of VR,
- tendency to become immersed in games, books, films and stories,

- physical reactions to wearing VR equipment, including any nausea, dizziness or disorientation they experienced,
- reactions to VA as a place, and
- views on the use of VR technologies in heritage and museum settings.

We received full ethical approval for this study from Bournemouth University for participants 16 years of age and older. All respondents received an information sheet explaining the study to them in detail, that they could withdraw at any time and assuring them that any personal data would be protected in line with all UK data protection law. All respondents signed an agreement for their data to be used for the purposes of this research. Any data that individually identified responses from any person taking part in the study was destroyed in September 2019.

Children under the age of 16 did experience VA but only by request from, and under supervision of, a responsible relative, and we did not collect any information from these participants.

2.3. Methods of data analysis

The questionnaire data regarding experiences of VA were drawn from Likert scales with four or five degrees of freedom, depending upon the question. Additional text comments could be added by respondents to every question. The observational data were noted at the time of the public evaluation events.

Overall, data were analysed using descriptive statistical methods for non-parametric (ordinal and non-normal distribution) data; for comparisons of responses to answers across the whole population, we therefore used median values rather than means. Associations between variables in the data from the Likert scale questions were investigated using two non-parametric statistical tests:

- Mann-Whitney-Wilcoxon (MWW), which tests the null hypothesis that the distribution of a particular variable is identical in two groups from a single population; this test was carried out using the 'R' statistical package, and
- Spearman Rank Correlation (SRC), which tests the strength and direction of an association between two variables; this test was carried out using a macro in MS Excel.

In SRCs, strengths of the association are inferred as 1=perfect, ±0.9-0.7=strong, ±0.6-0.4=moderate and ±0.3-0.1=weak. Correlations <0.01 or >-0.01 are inferred as showing no significant association. P values above 0.05 indicate less confidence in the findings, which is most likely due to insufficient variance in the data to prove or disprove a null hypothesis.

Qualitative data from the text boxes in the questionnaire, together with observation data from all public evaluation events, were analysed using a simple thematic analysis technique. Major themes in responses were identified and responses were then coded under these themes. Individual responses could be coded under any number of themes.

The full anonymised, cleaned, and coded data set of responses to the questionnaire, from which the findings in this paper have been drawn, are openly available at the Bournemouth University research repository[1].

3. Results

3.1. Demographic data analysis

Of the 388 questionnaire respondents, 280 were resident in the UK with the remaining 108 visiting from 17 different countries, viz. UAE, Austria, Australia, Belgium, Canada, Czech Republic, France, Germany, Italy, Netherlands, Norway, New Zealand, Portugal, Singapore, St Vincent and the Grenadines, Switzerland and the USA.

We compared the percentages in different age groups amongst UK respondents with the percentages of the UK population in the same age groups from the Office for National Statistics (ONS) estimation of the UK population in mid-2018 (ONS, 2020). This comparison, shown in Figure 5, demonstrates that age groups between the ages of 40 to 70 were significantly overrepresented compared to the general UK population, but as these age groups are more likely to be members of the National Trust and to visit sites like Avebury, this is perhaps not surprising. The higher representation in the 16-24 group is partly due to high school and college/university educational trips to Avebury as part of their curricula.

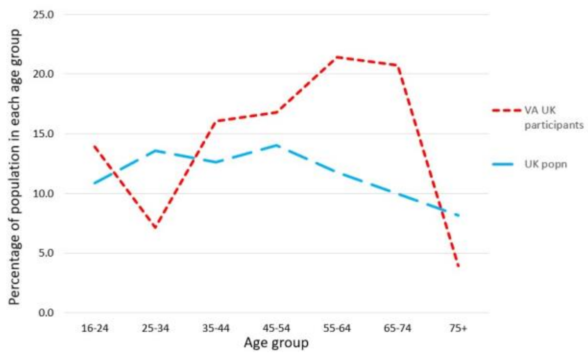

Figure 5: Comparison of UK population with UK VA respondents –percentage of population in each age group.

Figure 6 shows the total number of respondents in each age group from all nationalities, and the split between numbers of males and females in each group. The age distribution pattern of respondents overall is similar to that of the UK alone.

The gender distribution shows some variation between groups. We would stress at this point that all our questionnaire findings are from those visitors to Avebury who volunteered to experience VA and agreed to complete our questionnaire afterwards. This sample cannot therefore be argued to be representative of all visitors to Avebury, but it will be influenced by the general distribution of visitors.

One factor that may account for the male/female distribution of questionnaire respondents in the 65-74 age group did become apparent during our observations

[1]https://doi.org/10.18746/bmth.data.00000102

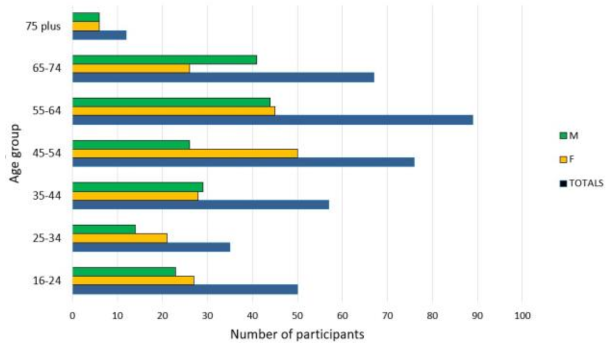

Figure 6: Age and gender distribution of all respondents.

of participants at Avebury. We noticed that grandparents bringing children to Avebury over the summer holidays were keen for the children to participate, and whilst the adult male would often participate too, the adult female would frequently decline and sit guarding bags and looking after those children waiting for their turn. When couples in this age group visited without children, females were more likely to participate. The causes for the increased participation of females in the 45-54 age group were not obvious from observation at the time, and neither do any particular differences emerge on analysis of all the questionnaire data.

Results of the detailed analysis of questionnaire responses are discussed in the relevant sections below.

3.1.1. Gender overall

Table 1 shows the results of the two-sample (male/female) MWW statistical tests on responses to questions relating to immersive tendency, respondents' experiences in VA, frequency of playing computer games and frequency of IT use. Differences between male and female answers are statistically significant where $p \leq 0.05$; these are shown in the blue shaded table rows.

Table 1: Differences in male and female responses overall

Question	*p*
Immersive tendency	0.0008
VA soundscape made me think about Neolithic people	0.01
VA helped me to find my way around Avebury	0.04
The experience helped to bring history to life	0.05
VA was believable as a place	0.22
I found the experience enjoyable	0.25
VR would be good in museums	0.27
VA gave me a sense of place	0.31
VA made me want to find out more about Avebury	0.38
VA helped me to feel closer to people who built Avebury	0.45
I would be more likely to visit heritage sites that had VR	0.66
Frequency of playing computer games	0.71
Frequency of IT use	0.93

These results show that immersive tendency was the only question where there was a very significant difference between male and female responses; this is discussed further in Section 3.1.4 below. Otherwise, three questions did show a significant difference between males and females (males tending to answer more positively than females in each case) but there was no statistically significant difference between male and female answers to the remaining questions, including frequency of IT use and frequency of playing computer games. There were some minor differences in responses to emotional reactions to VA between males and females and these are further discussed in Section 3.2.1.

Key findings: Overall, there was little correlation between gender and responses to the questionnaire, apart from the immersive tendency question and responses to feeling closer to Neolithic people, helping to find their way around physical Avebury after experiencing VA, and feeling that the simulation brought history to life.

3.1.2. Age overall

SRC tests were carried out on age data for all respondents against responses to the same questions as in Table 1. Correlation strengths are inferred as discussed in Section 2.3 above. Table 2 shows the statistically significant results in the shaded rows.

Table 2: Correlation between age and responses to questions overall

Question	*rho*	*p*
Immersive tendency	0.09	0.7
VA soundscape made me think about Neolithic people	-0.123	0.015
VA helped me to find my way around Avebury	-0.009	0.86
The experience helped to bring history to life	-0.028	0.58
VA was believable as a place	-0.019	0.71
I found the experience enjoyable	-0.003	0.95
VR would be good in museums	-0.07	0.17
VA gave me a sense of place	0.092	0.06
VA made me want to find out more about Avebury	-0.046	0.37
VA helped me to feel closer to people who built Avebury	0.024	0.63
I would be more likely to visit heritage sites that had VR	-0.112	0.027
Frequency of playing computer games	-0.357	0.0004
Frequency of IT use	-0.117	0.02

The questions relating to the frequency of playing computer games demonstrated the greatest correlation (negative), from which we infer that there was a moderate correlation between increasing age and decreasing gaming on computers. This is perhaps not surprising of itself; indeed, a stronger correlation might have been expected. We discuss patterns of computer game playing in Section 3.1.5 below as the outcome was not as straightforward as it may appear here. We also test to see if this tendency affected responses to VA.

There were weak negative correlations between age and

- the frequency of IT use,
- being more likely to visit heritage sites with VR and
- the soundscape evoking Neolithic people.

In each case, there was a weak tendency for positive answers to these questions to decrease with increasing age.

Key findings: Overall, there was little correlation between age and responses to the questionnaire, apart from a moderate decreasing likelihood of playing computer games with increasing age.

3.1.3. Disability overall

Fifteen respondents (13 ♀, 2 ♂) reported having a disability that they felt had affected their experience of VA including autism, motor function disabilities and eyesight impairment. Age distribution and the type of disability reported are shown in Table 3.

Table 3: VA respondents reporting a disability

Age group	*No of respondents*	*Gender*	*Forms of disability*
16-24	3	M=1; F=2	Mental health (2 x autism; 1 x undisclosed)
25-34	1	M=1	Vision (undisclosed)
45-54	6	F=6	Mobility (2 x problems with hands/wrists; 1 x back issues; 1 x hip issues) Vision (2 x undisclosed)
55-64	5	F-5	Mobility (1 x multiple sclerosis; 1 x transverse myelitis; 1 x undisclosed) Vision (1 x cataracts; 1 x loss of central vision in one eye)

There was no clear statistical association between reporting a disability and responses to the experience questions, but 15 is a small percentage (3.9%) of the 388 respondents and so these findings may not be statistically robust. The medians of responses to questions relating to nausea, dizziness, disorientation and discomfort when wearing VR equipment were the same for the group of disabled users as for the whole set of respondents, and none of the text comments of disabled participants made any specific reference to difficulties due to their disability. The medians of answers to questions regarding experiences of VA amongst disabled respondents were very similar to the total population (see Section 3.3 below), but once again, the relatively small sample size of disabled participants means this finding may not be statistically robust.

Our observations of participants with disabilities, and our conversations with them, gave us some helpful insights into their experiences and some good ideas for us to feed into further iterations of VA. In general, our observations matched up with the questionnaire data; that the equipment was generally well-tolerated and that disabled users enjoyed the experience. We received some interesting feedback in conversation, particularly about how an in-world guide, preferably an interactive one, would be helpful, especially for those with reduced physical mobility. For example, one lady in a wheelchair needed us to ‘drive’ the avatar using the touch devices whilst she wore the headset, and she was very appreciative that we could guide her around VA. She was keen on the idea of an in-world guide, maybe driven through Artificial Intelligence, that could be available any time to assist visitors to understand and explore the virtual site.

One experience was powerful for the team, involving a young man with autism who visited Avebury with his mother and sister. He was keen to try VA and we were careful to check with his mother that this would not be likely to cause him any distress. One of the young man’s symptoms was making frequent, sudden, loud vocalisations, but we noticed that these sounds stopped as soon as he entered the simulation and his general demeanour calmed whilst he was experiencing VA. His mother noticed this change too. As soon as he removed the headset and left the simulation, the vocalisations and general agitation returned. We offer this simply as an observation and draw no conclusions about the reasons for this effect, which are outside the scope of this paper.

Key findings: The VR equipment caused no specific problems for disabled users, but the sample size was small, and results may therefore not be statistically robust.

3.1.4. Immersive Tendency

The concept of immersive tendency relates to observed differences in how individuals experience presence in virtual environments, and it is estimated by the use of an Immersive Tendencies Questionnaire (ITQ) (Agrawal, Simon, Bech, Bærentsen, & Forchhammer, 2019) that asks questions relating to the tendency to get involved in stories, books, movies and video games, and how strongly respondents identify with characters in those media. A body of research has developed over the past 20 years that suggests an association between an individual’s immersive tendency and their sense of presence in a virtual environment (e.g. Jerome & Witmer, 2004; Kim et al, 2012; Rosa et al, 2016). Whilst we did not have the time to apply a full ITQ with our participants, we asked one question synthesised from the ITQ as a simple indicator of this tendency, to explore if participants’ experiences in VA, particularly sense of place, might be associated with their responses to the question “When you are watching a film or reading a book, how involved can you become with the story?”

Responses demonstrated the most marked difference between males and females in any of the questions on the questionnaire. Figure 7 shows that 61% of females reported getting completely lost in films or books, compared to 46% of males. The curve for males is more convex, demonstrating greater variance in the answers than for females. A MWW 2-sample significance test returned a value of p=0.0008, demonstrating a statistically significant difference between the two samples.

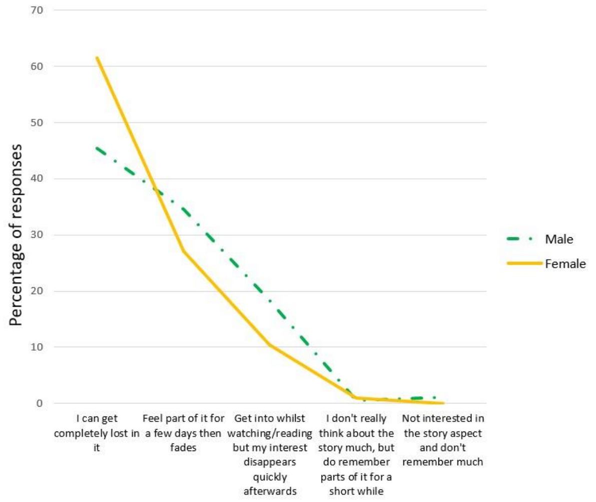

Figure 7: Male and female responses to the immersive tendency question.

Responses to this question for each sex were then tested for associations with responses to experiences of VA; the results are shown in Table 4 where the statistically significant findings are shown in the shaded rows. Note that in some cases where rho ≥ 0.1, p values were > 0.05, meaning these results have a lower confidence level.

Table 4: SRC with immersive tendency for males and females.

Question	*rho for male*	*rho for female*
VA soundscape made me think about Neolithic people	0.14 (p 0.05)	0.06 (p 0.36)
VA helped me to find my way around Avebury	0.176 (p 0.02)	0.03 (p 0.66)
The experience helped to bring history to life	0.05 (p 0.5)	0.14 (p 0.05)
VA was believable as a place	0.05 (p 0.53)	0.15 (p 0.03)
I found the experience enjoyable	0.116 (p 0.11)	0.23 (p 0.0009)
VR would be good in museums	0.13 (p 0.07)	0.1 (p 0.15)
VA gave me a sense of place	0.038 (p 0.61)	0.12 (p 0.09)
VA made me want to find out more about Avebury	0.23 (p 0.0014)	0.067 (p 0.33)
VA helped me to feel closer to people who built Avebury	0.105 (p 0.16)	-0.04 (p 0.53)
I would be more likely to visit heritage sites that had VR	0.10 (p 0.16)	0.12 (p 0.08)
Frequency of playing computer games	0.038 (p 0.6)	-0.028 (p 0.69)

Whilst Table 4 shows that the majority of responses for both males and females were associated with responses to the immersive tendency question, all associations were weak (rho < 3) and in several cases the confidence level of the association was > 0.05, which means we have a high level of uncertainty that immersive tendency had an influence on responses to those questions.

Key findings: There was a statistically significant difference in responses to the immersive tendency question between males and females, although there is uncertain evidence of the extent to which immersive tendency influenced respondents' experiences in VA.

3.1.5. IT/Gaming

Figure 8 shows responses to questions relating to the frequency of IT device usage, viz. mobile phone, tablet, laptop computer and desktop computer. We found some unexpected responses to questions relating to IT usage and computer game playing which signal the importance of avoiding stereotyping when it comes to the use of IT. In particular, responses to the question of how frequently participants used IT devices (mobile phones, tablets, laptops and desktops) showed no appreciable decline in the frequency of use until over the age of 55 and, even then, many respondents were still using these devices several times a week over the age of 75. As expected, the most widely used devices were mobile phones, with 91% of all respondents reporting that they used their phones daily, 3% reported using them less frequently, and 6% reported never having used a mobile phone. The age range for those reporting never having used a mobile phone (n=26) was 16-81, with the majority being in the 50-70 age range.

When SRC tests were carried out for frequency of IT use against responses to experiences in VA, no significant associations were found.

Relative frequency of playing computer games was one of the surprising findings. Whilst a reduction in frequency with increasing age is demonstrated by the data, the pattern in females is different from that in males, as can be seen in Figure 9. Overall, male game-playing shows a fairly regular reduction with increasing age, whereas female game playing does not. We did not ask any further questions about game playing as this was not the focus of our research, but this evidence does suggest that patterns of use of IT devices for game-playing may be more complex than the assumption that it is mostly the province of young males. In particular, females in the 65-74 age group reported almost twice the frequency of computer gaming to males in that age group, most of which is accounted for by games on mobile devices, e.g. tablets and smartphones. Console gaming was most prevalent in the 16-24 age group in both sexes, falling away rapidly in the older age groups.

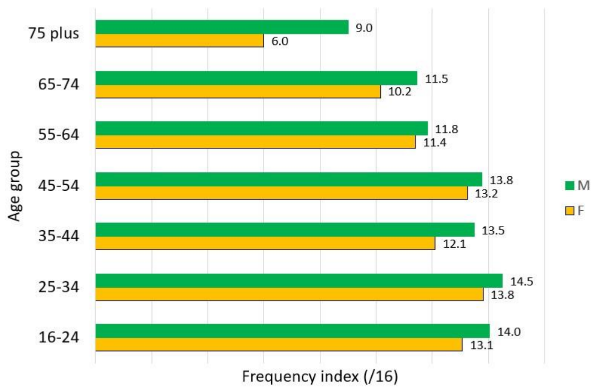

Figure 8: Relative frequency of use of IT by age/gender.

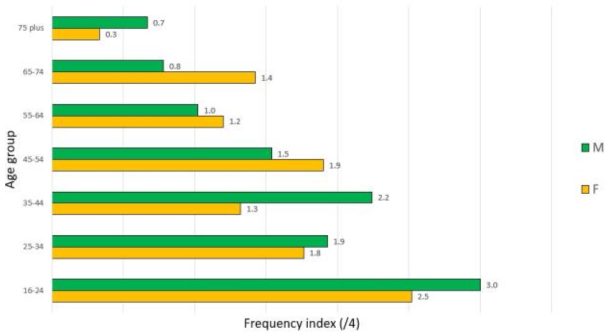

Figure 9: Relative frequency of playing computer games by age/gender.

We asked about gaming to see if the experience with computer games showed any relationship with responses to experiences in VA. SRC tests showed that there was no statistically significant association between frequency of playing computer games and responses to VA questions.

Key findings: Whilst the use of IT and playing computer games generally decreased with age, the pattern of use was more complex than that. Up to age 45, males played computer games more frequently than females, but between ages 45-75, females outplayed males by a significant margin. However, when IT usage and game playing were correlated against questions on VA, no statistically significant associations were found.

3.2. Responses to VA

Questions about reactions to VA resulted in generally positive responses, as shown in Figure 10. Respondents were particularly enthusiastic about the potential of VR technologies to be exciting and important additions to museums and heritage sites, although some respondents also had reservations and misgivings.

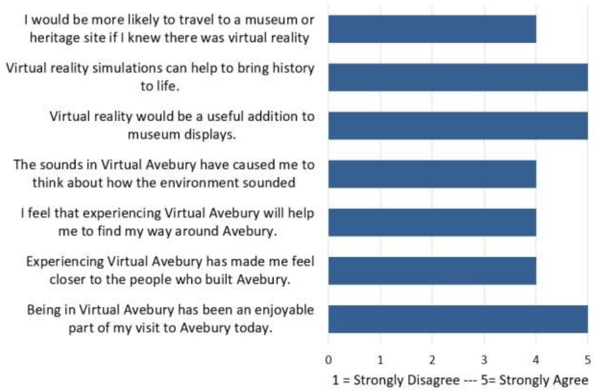

Figure 10: Median values for experiences of VA and opinions on the use of VR in heritage –all respondents.

A small selection of open text responses to the questionnaire demonstrates some of the differing views.

1. *"I think VR is a wonderful way to increase visitor engagement with the site and will allow for a greater understanding of the site as it once was."*
2. *"I feel very sure it would help but also concerned it would become too much of a focus, especially for children, for whom museums are a great way of developing close observation skills."*
3. *"It would bring the site to life. It is sometimes difficult to imagine how a site was when it was erected. Even with houses in the NT."*
4. *"I would prefer a seated theatre with a good quality animated video."*
5. *"But the dizziness/queasiness needs addressing."*

The sections below discuss the detail of responses to specific questions regarding emotional and physical responses to VA, believability, sense of place and the effects of soundscapes.

3.2.1. Emotional responses to experiencing VA

Experiences in VR are known to elicit emotional responses from participants (Diemer, 2015) so one of the questions asked respondents to choose from a range of offered emotions (any number could be chosen) and to add any emotions they felt at the time in a free-text box. Figure 11 shows the results from the question; in the free text area of the questionnaire respondents also added awed, exhilarated, amazed, funny, amused and fascinating.

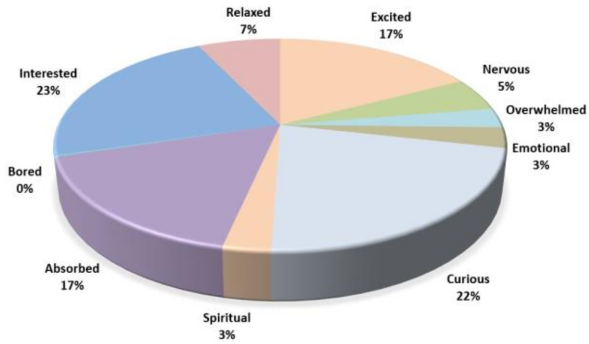

Figure 11: Emotions experienced in VA.

The four most frequently cited emotions were interested, curious, excited and absorbed. There were some differences in responses between age groups, but no obvious trends have emerged from the analysis. Again, no clear trends emerged in male/female responses except in the nervous category where, although overall only 5% of responses cited nervousness, almost twice as many females reported this compared to males.

Key finding: All respondents reported emotional responses to VA, with the majority reporting positive emotions. Some did report feeling nervous and/or overwhelmed, which is important to recognise when deploying VR at heritage sites.

3.2.2. Physical reactions to VR

We asked respondents to rate if using the VR equipment made them feel nauseous, dizzy or disorientated. The results for all respondents are shown in Table 5.

Table 5: Percentages (%) of respondents reporting nausea, dizziness and/or disorientation.

	A lot	*A moderate amount*	*A little*	*Not at all*
Nausea	1.8	10.1	40.2	47.7
Dizziness	3.4	11.6	53.1	31.7
Disorientation	3.1	7.5	49.2	39.4

Although some respondents did find the VR equipment made them feel dizzy, sick and/or disorientated, the majority of respondents, and all the users we observed during the public engagement phase, generally coped with the equipment well. 91% of respondents said that the equipment was very or reasonably comfortable and there was no correlation between age or sex and comfort/discomfort. Interestingly, there were weak correlations between increasing nausea (rho = -0.18) and dizziness (rho =-0.21) and decreasing age. This finding agrees with other research that shows a tendency for motion sickness susceptibility to decline with age (e.g. Paillard et al, 2013).

Key findings: Some users were physically affected by using the VR equipment, particularly with nausea and dizziness. Even though this was a minority, it is an important consideration when VR installations are made available for public use.

3.2.3. Believability and sense of place

It has been widely reported that computer game players can feel a strong sense of believability leading to a sense of place in computer game environments (see, for example, Bachen et al, 2015); in this study, we wanted to explore if believability might be an issue in a heritage setting when encouraging users to feel a sense of place.

50% of respondents felt that VA was very believable, 46% that it was fairly believable, with 4% responding that VA was not really believable. No one chose the “not at all believable” option. Two-thirds of the respondents had a strong sense of being in an actual landscape when they experienced VA, suggesting that they experienced it as a form of place. As discussed above, there were few statistically significant associations between age, gender, immersive tendency, frequency of IT use or computer game playing and the questions relating to believability and sense of place, and those associations that were found were weak. However, an association between feeling that VA was believable and experiencing a sense of place was apparent, with a moderate SRC (rho=0.5, p<0.0006) between the 2, suggesting that increasing believability was associated with an increasing sense of place. This finding cannot be generalised to mean that a simulated VR environment must be believable in order to engender a sense of place, but in this case, our findings suggest an association between the two for this heritage site.

Respondents were also asked to make any free text comments they wished. Twenty-nine responded, of which 13 related to the quality of the simulation, including the use of colour, 13 related to personal experience and 3 contained aspects of both. Generally, respondents felt that the simulation could have more depth to the colours, more realism in the graphics and that it felt a little empty at the time they used it. A sample of the comments is reproduced below as an indication. Comments 4 and 5 demonstrate the kinds of reactions participants had that gave them a sense of physical presence in the simulation.

1. *“It was amazingly realistic in terms of being able to move around, but as there were no people (apart from the static couple) or animals, and nothing moving, it wasn't completely believable.”*
2. *“Wow, I’d like to have gone further and interacted with village people and may be (sic) cook or do something more constructive.”*
3. *“Find it difficult to separate the knowledge that it is not real. I never find movies to be real.”*
4. *“It felt slightly disorientating due to the slightly jerky movements. I do have a fear of heights and when I walked to the edge of the ditch, that kicked in, so that was real enough. Also when flying I couldn't go beyond the walls as I couldn't get a sense of what was beyond (in terms of my fears).”*
5. *“I even flinched when I nearly walked into a rock!”.*

Key findings: The majority of respondents reported feeling that VA was both believable and gave them a sense of place. We found a moderate correlation between believability and sense of place, suggesting that these two reactions may be associated.

3.2.4. The effect of sound

One aspect of VR simulation that can be overlooked is the importance of sound in creating a sense of presence in a virtual environment. In VA we created a soundscape that changed as participants moved through the landscape, comprising elements of weather, human activity and sounds of those animals that would have been native at the time of the simulation. Responses to questions about its effect are summarised in Fig. 12; note that respondents could choose any number of the offered responses.

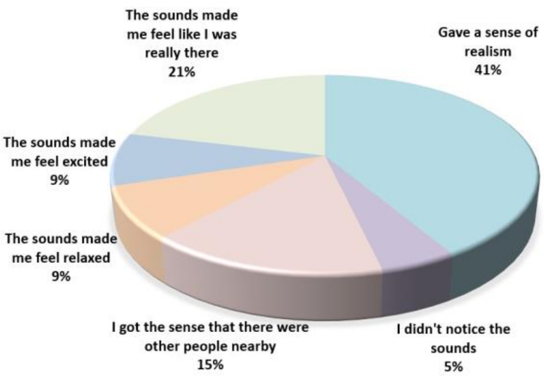

Figure 12: Responses to questions regarding the effect of soundscapes.

The most frequently chosen response was that the sounds gave a sense of realism to the simulation, followed by giving respondents a sense of place (feeling like they were really there). The least frequently chosen response was not noticing the sounds, although this was chosen by 34 participants out of 388 (approx. 9%) and as such is a finding worthy of consideration. There were no disclosed disabilities relating to hearing (see Section 3.1.3) and so not noticing the sounds was unlikely to be due to not being able to hear them. Whilst the majority of respondents did feel that the sounds had an effect on their experiences, it seems from the free-text responses that some people are less sensitive to sounds than others. Several respondents also commented that some of the sounds, like human voices, had no obvious source; they found this strange and so ignored the sounds.

Key findings: Sounds were an important element in providing a sense of place, but VA needed better-located sounds and a clearer source of human and animal sounds.

4. Conclusions and recommendations

Whilst the focus of this project was on the sense of place and enjoyment that lay users might experience through the simulation, we recognise that this cannot be considered in isolation from a range of issues that are pertinent to simulating heritage sites in immersive technologies. As we discuss at the beginning of the paper, issues of authenticity, scientific and interpretive rigour and how public users were made aware that VA was one representation of a number of alternative hypotheses regarding Avebury, were vital issues. But as Statham (2019) argues, there is little specific support for those working in 3D heritage visualisation in terms of guidelines and accepted methodologies, and practitioners and researchers in this field are still in the process of developing an understanding of both what is possible, and what is desirable. For example, in her review of 32 charters, principles and guides from the International Council on Monuments and Sites (ICOMOS) and United Nations Educational, Scientific and Cultural Organization (UNESCO), that broadly relate to scientific guidelines for visualising heritage, Statham cites just 2 that specifically relate to the digital visualisation of heritage. These are The London Charter (London, 2009) and The Seville Principles (International Principles of Virtual Archaeology, 2011). But these recommendations tend to be high-level principles that are concerned with authenticity and scientific rigour, as demonstrated by the application of the London Charter principles to this project. In the editorial introduction to a special issue of the journal Presence on VR for cultural heritage, Ch'ng, Cai & Thwaites (2017: iv) comment that VR technology itself has become mature enough to facilitate experiencing virtual heritage simulations, but that it is "…unclear where we are in terms of how well the research community and cultural institutions are doing with the technology." We would therefore recommend that future research might focus on the characteristics of successful virtual heritage simulations with a view to creating guidance on how 3D platforms and immersive technologies can best be used for public engagement with heritage.

It is our contention that public engagement is a vital part of digital heritage visualisation (see, for example, Taylor & Gibson, 2015). However, prior to the public testing of VA we encountered a sense from colleagues working in the heritage sector that VR interpretations of ancient sites might be more attractive to younger visitors or those who were more familiar with IT use, and might actively dissuade older people or those less familiar with IT from engaging with museums, if they have a significant VR offering. However, our results showed that for our population, reactions to VA and experiences in the simulation had little significant association with demographic data. We are not claiming that these findings are generalisable, but that they do suggest that VR simulations might be appreciated by a wide range of museum and heritage site visitors. Notwithstanding this, our observations showed that some older visitors needed more encouragement to try the simulation than younger age groups; once they were 'in', their experiences were very similar to all other age groups. We would therefore recommend that, at heritage sites that have a VR simulation, consideration is given to how older visitors might be encouraged to participate.

Regarding believability of VR simulations, Magnenat-Thalmann, Kim, Egges & Garchery (2005) identify 3 elements of believability that relate specifically to virtual environments, viz. immersion, presentation and interaction. Our data shows that our respondents varied in their immersive tendencies, particularly between the sexes, and that immersive tendency may have had an effect on some of their experiences, but that the evidence is not clear. However, their responses to questions about their emotional reactions to VA did demonstrate that many respondents had become absorbed, excited and/or curious during their experience, all of which are facets of immersion. Specific questions regarding the look, feel and sound of the simulation (presentation) elicited positive responses, as did specific questions regarding believability. We did receive both written and conversational comments that participants would like to have had more opportunity for interaction, and of the 3 elements of believability, this was the least available in VA. Two people could be in the simulation at the same time, and this happened frequently as we often had 2 VR sets available. But we did find that they were often so absorbed in the visual simulation, the ability to fly and the opportunity to explore farther afield than the henge itself, that little interaction actually took place.

Regarding sense of place, the reactions we observed while participants were in VA, coupled with responses to questions regarding their generally strong sense of being in an actual landscape, demonstrated that most participants did experience a significant sense of place. This finding is further reinforced by the moderate correlation between responses to sense of place questions and believability questions. This was one of the strongest correlations we found between any of the constructs tested by the questionnaire. This does not mean that there is a causative link between sense of place and believability but, in our sample, there was a positive association between the two, i.e. if a participant experienced a sense of place, they were moderately likely to feel the simulation was believable, and vice versa. This correlation agrees with other studies that have discovered an association between these 2 constructs in virtual heritage environments (see, for example, Belotti, Berta, de Gloria, Panizza and Primavera 2009) and strengthens the recommendation we make above, that there is a need for more specific guidance on the characteristics of virtual heritage simulations that can result in effective public engagement.

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