A Design Framework for Smart Glass Augmented Reality Experiences in Heritage Sites.

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Despite the growing applications of smart glass Augmented Reality (AR) in heritage, there is not a framework that can serve as a base for designing meaningful and educational immersive heritage experiences. This article proposes such a prototype design framework for AR experiences in heritage sites, drawing on literature that connects affective experiences with learning, and practically exploring AR as a non-didactic storytelling medium. Smart glass AR is considered here an important technology milestone for creating affective interactions, one that offers visitors/viewers new ways to experience, embody, and have a physical and social interaction with a localized past, and learn about it.

CCS CONCEPTS • Applied computing ~ Arts and humanities ~ Media arts • Human-Centred Computing ~ Interaction Design ~ Interaction Design process and methods • Applied Computing ~ Education ~ Interactive Learning Environments

Additional Keywords and Phrases: Augmented Reality, Smart glasses, Heritage, Affect, Narrative, Storytelling, Framework, Hololens

ACM Reference Format:

First Author's Name, Initials, and Last Name, Second Author's Name, Initials, and Last Name, and Third Author's Name, Initials, and Last Name. 2018. The Title of the Paper: ACM Conference Proceedings Manuscript Submission Template: This is the subtitle of the paper, this document both explains and embodies the submission format for authors using Word. In Woodstock '18: ACM Symposium on Neural Gaze Detection, June 03–05, 2018, Woodstock, NY. ACM, New York, NY, USA, 10 pages. NOTE: This block will be automatically generated when manuscripts are processed after acceptance.

1 INTRODUCTION

Cultural heritage has always been a fertile area for experimentation and application of immersive technologies. The advances in commercial Augmented and Virtual Reality technologies (AR/VR), and particularly mobile AR, have increased their adoption by the heritage industry as they offer visitors an alternative way to experience their exhibits and spaces. In their robust review of immersive technologies for cultural heritage (Bekele et al. 2018) recognised three hurdles that prevent the acceptance and diffusion of immersive technologies, including AR, in cultural heritage: (i) technological limitations, (ii) content complexity, and (iii) human factors. In addition, often the design of AR applications does not consider the richness of stories connected to the heritage places nor taps

1556-4673/2021/MonthOfPublication - ArticleNumber $15.00

http://dx.doi.org/10.1145/3490393

into their full dramatic potential for engaging the viewers through storytelling, a tool that museums have been using successfully for over 70 years (Papagiannakis et al. 2018). Museums are rich 'narrative environments', experiences which integrate objects and spaces — and stories of people and places - as part of a process of storytelling that speaks of the experience of the everyday and our sense of self, as well as the special and the unique' (McLeod, Hourston and Hale 2012). In museums stories have traditionally been told through written and spoken word, using tools such as labels, audiovisual guides, booklets, and live performance. The last decade has seen an emergence of tools that assist interpretation teams shape museums as narrative spaces involving in the process the creative industries such as architecture, film, theatre, games design, digital media, and graphic design. Stories are told in a multitude of ways making connect with human perception, imagination and memory (McLeod, Hourston and Hale 2012). Immersive heritage technology design, with the design goal to bring the past to life, has for long concentrated on the representation of the past (e.g. Narciso et al 2015; Panciroli, Macauda and Russo 2010). Notwithstanding the importance of this research, there is an opportunity missed for harnessing the technology as a storytelling vehicle rather than making it the center of the experience. The latter approach often results in visitor experience that may be educational but is so in a way that is disjoined from the full interpretative potential of the place it develops in. In addition, museums progressively apply 'post-digital' design processes, where the digitally-mediated visitor experience is viewed holistically, taking into account their embodied interaction with the physical space (Ciolfi 2015), and embedding the digital within all museum practices without viewing it as a separate medium (Mason 2020), AR design that considers this approach and explores more in-depth, embedded experiences than a simple superimposition of 3D material on the physical space, has the potential to engage the visitors in more meaningful interactions. In the latest years there have been some attempts in mobile AR (Papagiannakis et al. 2018; Liestoel 2011; Spierling, Winzer and Massarczyk 2017) and smart glass AR (Krzywinska et al. 2020; Jin, Ma and Liu 2020, Old and New 2018) to investigate narrative techniques and explore storytelling, presence, and gamification as an interactivity layer that offer visitors opportunities for meaning making leading to more engaging interactions.

The work presented in this paper considers and analyzes these hurdles and attempts to place a starting point for a framework to support the creation of meaningful AR-enabled learning experiences in heritage focusing on affective storytelling. In doing so it uses the emerging technology of AR smart glasses, a pair of glasses through which the viewer can see virtual, holographic material superimposed in the physical environment in a realistic way. AR smart glasses are an appropriate device because, as narrative takes centre stage, the technology must be able to communicate the complex audio-visual and interaction layers of the experience in the least encumbered way. (Leue, Jung and tom Dieck 2015) found that traditional devices such as audio guides or smartphones and tablets are perceived as cumbersome and impractical by visitors. Mobile devices need to be held at all times causing fatigue, while viewing the physical space augmented with the digital material through a small screen creates a digital divide that does not help build a sense of embodiment. AR smart glasses offer a new interaction method that is hands-free, see-through so that the viewer never loses sight of the actual space and have several methods to acquire and utilise sensorial information from the user such as eye and gaze tracking. (Mason 2016) showed that looking through an AR smart glass see-through display offers a more immersive experience than that offered by mobile devices, since visitors can maintain better awareness of their context when receiving information.

The presented work considers heritage sites, as opposed to exhibition-led museum spaces, as the primary space where the AR experience unfolds. This is because heritage sites are inherently sensorial, immersive spaces with the tangible heritage evident on display through the architecture, the interior, and the smells and natural

sounds that accompany a non-digital walkthrough of the site (Kidd 2018). Being present in a heritage site eases the making of associations between the place and the visitor's understanding and appreciation of the historical landscape, helping form what (Champion 2006) called 'cultural presence', a feeling of inhibiting the historic place there and then, in a meaningful way which in turn immerses people spatially and thematically into a cultural learning experience. In design terms, the existing setting and arrangements allow heritage sites to be perceived as 'stages' that offer more opportunities for affective, digitally-mediated interactions than exhibit-led museums. Apart from focusing on heritage sites, the practical case study took place in an indoor space as the quality of the holographic material of AR smart glasses is largely affected by light. Too much of natural or excessive artificial light makes the details of virtual objects difficult to distinguish, and since heritage sites are open predominantly during the day, the decision was to focus on the indoor spaces with moderate lighting.

The proposed framework was created and is fundamentally based on a transdisciplinary approach to creating these experiences. (Pohl 2011) defines transdisciplinarity as a collaboration focused on knowledge production by developing a comprehensive, multi-perspective, common-good oriented and useful approach to a socially relevant issue. A transdisciplinary approach is important in cases where knowledge production and problem solving are quite complex, and involve many traditional disciplines, and discipline-specific knowledge. In such projects, participants who come from different disciplines and sectors to co-create are invited to (1) understand and analyse underlying complexities, (2) take into account and connect diverse theoretical and practical perspectives and knowledge, and (3) be open to breaking down disciplinary boundaries so that a new, common, perspective and knowledge surfaces (Hadorn, Pohl and Bammer 2010). The framework was developed through a fuzzy process where interaction designers, historians, AR developers, museum educators, and visitor experience experts, worked together in between (1) - (3) to create and develop Sutton House Stories, a smart glass AR experience for a Tudor house and National Trust property in London, UK.

The framework that will be presented and discussed through the design case of Sutton House Stories is not meant to be a unifying framework. It presents one design approach that focuses on AR as a storytelling medium and views the design through a dramaturgical lens to help create affective experiences. It is documented in this article as a starting point for researchers and practitioners who wish to assess it and develop it further.

The remainder of this article is structured as follows: Section 2 introduces the connections between affect and learning. Section 3 introduces Sutton House Stories, and describes its evaluation and feedback discussing also related projects from the literature. Section 4 introduces the framework by discussing the feedback and clustering the insights into the framework's design pillars, while Section 5 concludes with some thoughts for the future.

2 BACKGROUND

2.1 Learning through Affective Storytelling

Learning in heritage sites is experiential, enactive and situated. It happens while visitors walk through the physical space, using all their body, senses, and imagination. A heritage site, either full of furniture and objects or empty, is a tangible and intangible manifestation of the past. Whether visitors traverse it alone, in a group, with a tour guide or an audio guide, they experience it in different ways and they construct their own personal meaning based on this experience (Hale 2012). Experiential (Kolb 2015) and situated learning (Lave and Wenger 1991) is at the heart of modern heritage interpretation aimed at provoking the audience to learn about issues related to the site, construct and discover personal meaning, and forge personal connections with things, places, people, and

concepts, rather than simply communicating information through displayed artefacts (Ham 2013; Silverman 1995; Weil 1997). Storytelling has been a fundamental tool to achieve this (Bedford 2001).

(Bruner 1990) describes how humans makes sense of the world by telling and listening to stories. Stories invite a moral reflection and judgement, becoming consequently a tool that helps us shape our core values and beliefs. Therefore, storytelling in museums does not only support intuitive learning but also helps visitors frame historical narratives, and reflect on them making sense in the process of themselves. Authentic stories help with the design of the visitor's trajectory in the site and help communicate its cultural significance in a seamless manner that allows and promotes visitor imagination. (Bedford 2001) writes that 'more than anything else, then, stories are powerful because they do not fill in all the blanks. They open up a space into which the listener's own thoughts, feelings, and memories can flow and expand. They inspire an internal dialogue and thus ensure a real connection'. Equally important is how these stories are told, and how close they can be to the other interpretation available on site (Kidd 2018). There is a plethora of different ways to communicate stories. In this framework I focus on ways that are less didactic, in the sense that the audience is told a story, but instead on ways that allow them to create it themselves in what (Bucher 2017) described, in his overview of storytelling for virtual reality, as "less about telling the viewer a story and more about letting the viewer discover the story." I interpret Bucher's point of view as letting the viewer immerse themselves in the hybrid physical/digital space in a natural and meaningful way, offering them opportunities for interaction rather than prescribed interactions. This perspective further allows not only the articulation and communication of historic facts but also a wider opportunity for interpretation to offer provocations related to these facts, for example questions about social justice, representation, and identity. In heritage sites, inviting meaning making through stories is reinforced by the environment. The stories are presented (and often performed) in the presence of the built environment with its objects, smells and sounds, and the hybrid space that is created to support storytelling allows for a felt, embodied and enactive experience of meaning making (Hale 2012). Combined together, I refer to these aspects of the experience as 'affective' drawing on (Pais 2016)'s definition of "affect" as 'the sensitive charges or felt intensities carried by words, sensations, thoughts and emotions that circulate in social spaces'. The affective factor in the creation of the story around a place fuels experiential learning which has always been important to heritage sites. Research has demonstrated that emotional engagement is closely associated with learning (Sylwester 1994; Bower 1992; Dolan 2002). Emotional responses to learning materials have been shown to increase motivation, attention, and facilitate effective learning (Wolfson and Case 2000; Taylor 2014; Zull and Statler 2016; Savenije and De Bruijn 2017), while heightened emotional involvement makes the learning content memorable and for longer periods of time than with emotionally neutral involvement (Ninaus et al. 2019; McCrary 2002; Phelps 2004). Stories are powerful means of emotional engagement and the affective experience of learners through storytelling has been explored in online and multimedia learning environments (Mcquiggan, Robison and Lester 2008; McCrary 2002) and in heritage (Economou, Young and Sosnowska 2018; Savenije and De Bruijn 2017; Petrelli et al. 2016).

Smart glass AR experiences can additionally support learning through enactive, multi-sensory approaches to interacting with the learning material, particularly when user interactions are designed in the narrative. The idea of enaction involves experiencing, interacting with and making meaning of the world through sensory-motor and affective processes. (Gallagher and Lindgren 2015) have argued for an approach to learning through whole-body engagement in a way that employs enactive metaphors and have demonstrated how whole-body enactive interactions create a positive space for learning and knowledge retention. (Enyedy et al. 2012; Johnson-Glenberg et

al. 2014; Antle, Droumeva and Corness 2018) particularly mention the affordances that AR environments have for engaging learners in enactive activities, and, in heritage, (Gregory and Witcomb 2007) and (Hale 2012) have argued that heritage sites which can facilitate an embodied learning experience can more easily elicit an affective response and stimulate empathy.

If affective storytelling is the design driving force for the AR experience, then the result is an engaging activity that supports experiential learning. This thesis subsumes the methodology that was developed for Sutton House Stories and which became the starting point for this framework.

3 SUTTON HOUSE STORIES

Sutton House Stories is a 4 minutes long smart glass AR experience using Hololens 1, designed and developed in 2019 for Sutton House, a Tudor house in the London Borough of Hackney (UK). The viewer puts on the headset and walks around the Great Chamber, the largest room in the house, and is guided by three voices who represent three key figures that lived in the house across four centuries, Ernest Alfred Munday a WWI soldier who frequented the house when it was a Church Institute for Men (1900-1918, Chapter One), Mrs Freeman, a headteacher when the house was a girls' school (1647-1752, Chapter Two), and Sir Ralph Sadlier, who built the property and was Secretary of State for King Henry VIII (circa 1555, Chapter 3). Professional voice actors were employed to act out the script in the form of a monologue as if they are talking to the viewer. While viewers listen to the narrators, they see and hear superimposed content which is related to what they hear and additional content which is not (Figure 1). At certain points they also can interact although this is not made explicit to them. For example, there is a sequence where a pair of dance shoes perform a minuet, a popular dance during the Georgian period (Figure 2). Viewers are free to walk around the dancing shoes and watch their dance and even try to mimic the steps.

Fig. 1. A visitor with the Hololens on. Image shows the north and west side of the Great Chamber.

Fig. 2. A visitor with the Hololens on looking at the virtual minuet dancing shoes. Image shows the south side of the Great Chamber. Combined footage of real space and AR view.

Viewers move between sequences by clicking virtual pins using a specific 'pinching' gesture in the air. The experience finishes with a virtual window opening on top of the real one to reveal an impression of the areas's countryside as it used to be at the time the house was built (Figure 3). The experience was designed during two full day workshops that gathered the house's historians, educators, visitor experience experts, the AR developers, and the author as an interaction designer. During the process of constructing the narrative, the possibilities and limitations of the headset were discussed against ideas, the house's staff prioritised the learning material they would like communicated and the opportunities for interpretation that the new technology provided. The process was fuzzy, multi-faceted, and at times required creative problem-solving that involved all disciplines. However, it was clear from the beginning that the stories were at the centre of it. The content design process has been thoroughly documented in (Dima forthcoming). The workshops were developed based on a design-as-doing dramaturgy approach (Dima forthcoming), a framework that borrows from theatre to design immersive experiences. The role of the viewer is one of the first building blocks and early on there was a suggestion to create an overarching story and give the viewer a role in it, making the experience more like a game. This was discussed thoroughly due to the complexity it introduced for the visitor given they will have to work through the novelty of the headset, and there were also concerns about balancing game mechanics with affective storytelling in the short timeframe that is the optimal for an experience with a headset. In addition, not all visitors are comfortable with playing a game, regarding it as a disruptive activity against a more solemn and quiet walkthrough of a historic site that allows introspection and absorption (Poole 2018). Considering different levels of engagement with processes of historical construction is a democratic design practice that will be useful for learning as audiences become more familiar with AR headsets. Arguably, a fully gamified experience may not allow complete emotional immersion and

needs to be carefully designed so that the gameplay does not dominate the experience making finishing the game the primary goal of the visitor. In Sutton House Stories this balance was kept by focusing more on creating opportunities for play (which can broadly be contrasted to games as a non-goal-oriented activity) than a game, such as the minuet dance, and designing in components that suspended further the disbelief to create a 'humane' experience.

Fig. 3. The water coloured virtual view out of the window. Combined footage of real space and AR view.

3.1 Evaluation

The experience was evaluated to compare the effect that it had in the visitor's learning as opposed to a normal visit of the house, and to understand how visitors perceive this new technology, how they connect with and use it to make meaning of the house's histories. The qualitative evaluation included observing the participants during the experience, focus groups, and a tailored Personal Meaning Mapping (PMM) exercise pre and post experience. In total, 36 participants took part in the evaluation in 5 groups and as six individuals. Among them was a group of the Sutton House staff, three who had participated in the initial workshops and two who had not. Participants were invited through a targeted call while four of them were random visitors during the days of the evaluation who showed interest in participating. All participants were adults and six of them were in the age group 55-70 with two of them having mobility issues. The evaluation took place over 5 consecutive days.

Situated learning is a complex process which cannot often be measured with a short-term evaluation. Based on the literature that connects engagement with learning, the evaluation sought to monitor participants'

emotional engagement as a measure of learning in addition to their direct reflections of their experience through the PMM and during the focus groups.

3.1.1 Personal Meaning Mapping

PMM is a responsive research methodology developed by (Adams, Falk and Dierking 2013) to capture the multi-faceted learning experience of museum visitors by focusing on the visitors' personal interpretations and how their individual backgrounds help them emerge. The author's work is based on the premise that learning is a relative and constructive process (Adams, Falk and Dierking 2013) that is dependent on personal, socio-cultural, and physical contextual factors. In order to form a holistic understanding of the learner's process researchers need to take these factors into account when evaluating the learning experience. The methodology brings the visitor's agendas at the center as opposed to top-down research methodologies that aim to promote the museum's agenda, such as pre-defined visitor experience questionnaires. PMM has been widely used in the heritage context. During the PMM activity participants are provided with a blank paper on which a prompting word, name, phrase or image is positioned in the middle. They are then asked to write down anything that comes to mind around this central concept developing it in the way of a mind map. When they are finished, they are interviewed about what they have written and are asked to elaborate on it. The interviewer amends the mind map with the expanded responses with a different colour ink. When visitors finish their visit, they are asked to revisit their map and make any alterations in a different colour ink. They are then interviewed about their changes. This allows the interviewer to observe any changes in knowledge pre and post visit. PMM analyses then is taken both within and across individuals.

Due to its focus on understanding the learning experience of the visitor and the importance it poses on the visitor's unique background, PMM was considered an ideal tool for the evaluation of Sutton House Stories. However, it was used with one adaptation to better suit the research questions of the project. The evaluation's aim was to observe, record, and analyse the change in knowledge, understanding and behaviour between a visit of the house with and without the glasses rather than an in-depth, horizontal, understanding of the visitor's meaning-making in each case. Therefore, the individual interview with participants after they completed the pre-experience map was removed. Instead, there was a post-experience focus group, which allowed participants to move from self-reflection to joined reflection that is triggered by other people's prompts. The advantage of having a focus group is that together with the self-reflection that takes place while creating the maps there is a collective reflection that enriches the ways participants think of their experience. The author maintained a facilitator role in this. Before the focus group, participants were asked to create the post-experience map, on their own, and amend it if needed after the focus group. The comparison between the pre- and post-experience was analysed by looking at the difference in the maps within and across individuals and combining this with their feedback during the focus groups. Due to the holistic approach to participant's feedback through the maps and focus group discussions, which is the advantage of the PMM, there was no need to follow other known methods for qualitative analysis such as content analysis.

According to (Adams et al. 2013) the prompts at the center of the map are created with a focus on the required exploration topic and their ability to elicit meaningful responses, and are indeed part of the art of designing the PMM methodology. The focus of this research is to understand the relationship that is formed between the visitor and Sutton House as a physical space and historic place, and, in the case of Sutton House staff, as their normal place of work. Therefore, the prompt for this activity was 'Sutton House' and it was written at the center of both sides of a card participants were given shortly before their visit started. They were asked to go around the house, and reflect and write anything that comes to mind on the one side of the card. They were also given a small map of

the house, which is normally available to visitors. The walkthrough for each participant or group varied in time with a mean duration of 20 minutes. Visits were not shorter than 15 minutes and no longer than 30 minutes. The walkthrough finished in the Great Chamber room where they put on the headset and went through the AR experience. They were then asked to fill in the other side of the PMM card, with a different coloured pen, which included the same task of reflecting and writing down their emotional response and connection with the place after getting acquainted with it through the AR experience. After everyone from the group had completed the experience and the mapping exercise, they were invited to a 30-minute focus group discussion.

3.2 Results

3.2.1 Situated Learning

The result of the PMM offered particularly fruitful insights on the participants' situated learning, and on the difference of how this happens with and without the AR glasses. There was a common description of how the house and its history changed between the two experiences with the use of the words 'alive', and 'came to life'. 90% of participants used this word to describe how they viewed the house after the AR experience whereas a big percentage mentioned that they connected deeper with the place and the people that were part of its history, often using the phrase 'emotional connection' to describe this. In contrast, their maps before the AR experience included description of the physical place, in terms of objects, sounds (e.g., "creaking steps"), and sensorial details such as "brick walls", "dramatic lighting", "eerie stillness".

There was strong evidence of situated learning as 85% of participants wrote and discussed the new historic knowledge they gained through the AR experience. On their post experience maps they mentioned that they learned about the person who built the house, how the house was used across the centuries, and how the surroundings looked like back then. As the AR experience happened at the end of their visit, this evidence indicates that they would normally leave the house without this information, even though it was given to them through labels scattered around the house. Knowledge retention was also evident in a few participants. During the focus groups a few would use the soldier's name to refer to him. One participant could not remember it but emphasized that although they cannot retain his name, they will certainly remember his story and that the house was used as a men's institute. The exact or approximate knowledge retention is in accordance with what (Ballagas, Kuntze and Walz 2008) found when evaluating their AR heritage game.

Many participants commented on the personal connection to individuals and their stories and how a historic layer becomes more obvious and stays better as a memory through them. One participant said: "*I got a lot more emotionally involved with the stories. When I was walking around the house, I maybe glazed over the signs but when I was doing this, I was actually paying attention and I felt much more involved. I guess connected to the story of the house, I actually cared who the next caretaker was*". Listening to the characters and their stories created for participants a deeper connection with the place, which was evident in the post-experience maps and focus groups. One noted how they wanted to know even more details about their everyday life, for example how did the WW2 soldier's parents react to his decision to join the front. They mentioned that the more detailed information they were given the more they would care about the person.

A phrase that was repeated extensively in the personal meaning maps was 'more humane'. According to one participant, the AR experience gave them an in-depth, lively sense of the intangible histories of the house which is hard to imagine when present in the house's stillness. The focus groups and a few of the post-experience maps

evidenced a strong desire to know more about the house after the AR experience. All staff members who were part of the design workshops had a profound emotional response to the AR experience despite already knowing in depth its history. According to them, the way the final story uncovered the many layers of history, and knitted them together with the use of archival material created a deeper level of engagement for them.

All participants favoured and spent most time at two parts of the experience: the minuet dance and the window overlooking the countryside. Analysis showed that the reason behinds this is that both went considerably beyond conveying historical facts. They offered an emotional audiovisual window to the past that is no longer possible to experience and did so by allowing the viewer time to reflect or interact. Looking out of the virtual window showing the watercolour stylized countryside was a visual impression of the change that the wider neighbourhood has gone through. The minuet offered a point of interaction for those participants who were interested in following the steps but also the laughs of the girls and the voice of the headteacher made the dance more lively. The scene also showed the relationship between the teacher and students. One participant said "*Oh it is so real! And the visuals of the feet with the giggling of the girls as a combination, the feet would not have interested me without the giggling [...] The audio is the thing that gave me an emotional response more than the visuals I think'.* This insight further strengthens the role of sound in transporting visitors to other historic periods as has been proven in many heritage audio walking tours (e.g. the work of the PastPorte company (Blackler 2018)). However, one participant noted that they were giving more attention to the visuals than listening as this is their preferred style of learning. They suggested that adding some sort of text within the visual material at specific points relevant to the narration would reinforce knowledge retention for people with this learning style. Both the minuet and window moment were created to communicate the cultural significance of the dance, the music, the social function of a girls' school in the specific era, and the surroundings of the house as the people who lived back then experienced them. (Champion 2006) writes that conveying cultural significance helps create cultural presence, and consequently, deep connection.

The physical aspect of the experience was strong without the AR headset, however, many participants commented that the virtual objects and character, even without many interactions with them, enriched the physical space which they could still see through the glasses in a visceral way, almost as if revealing a different world that waits to be discovered. Particular mention was made to the fireplace, which had a virtual fire burning with accompanied sound, Sir Ralph Sadlier sitting on his desk and writing, and the letters scattered on the desk, a burning candle nearby, and a virtual portrait of a female artist painted live on a real easel (Figures 4 & 5). The fire and letters were examples of elements that were designed not to be immediately visible but items waiting to be discovered. Most participants mentioned that they would have liked to be able to interact with the virtual objects, such as closing the curtains or feel as if they were touching them. Parts of the story offered a zone for physical interaction. Some participants wanted to follow the dance steps of the minuet, others wanted to grab and read Sir Ralph's letters, while the combination of the real window with the virtual nature outside created an evocative atmosphere that left people pausing and contemplating for some time. A few participants mentioned the enjoyment of the AR experience on a very personal and quiet level without needing to engage with or actively listen to a tour guide but engage with the augmented physical space in the way and pace they wanted to. These discussion points strengthen the importance and uniqueness of creating an embodied and enactive experience, which as (Hale 2012) suggests, drawing on phenomenology, is fundamental to constructing meaning. A few participants who were part of a weekly social club that meets at the house emphasized how wonderful it was to get to know the history of the place across the centuries through the different communities that occupied it making a seamless connection with how they

themselves use it now. Adding to this, several participants found the ending phrase, *"Will you share these memories so they are not forgotten?"*, a lovely way to end the story and tie together the narrative and the purpose of their visit. One participant mentioned that the experience gave them a sense of melancholy.

Fig. 4. Painting the virtual portrait on the easel. Combined footage of real space and AR view.

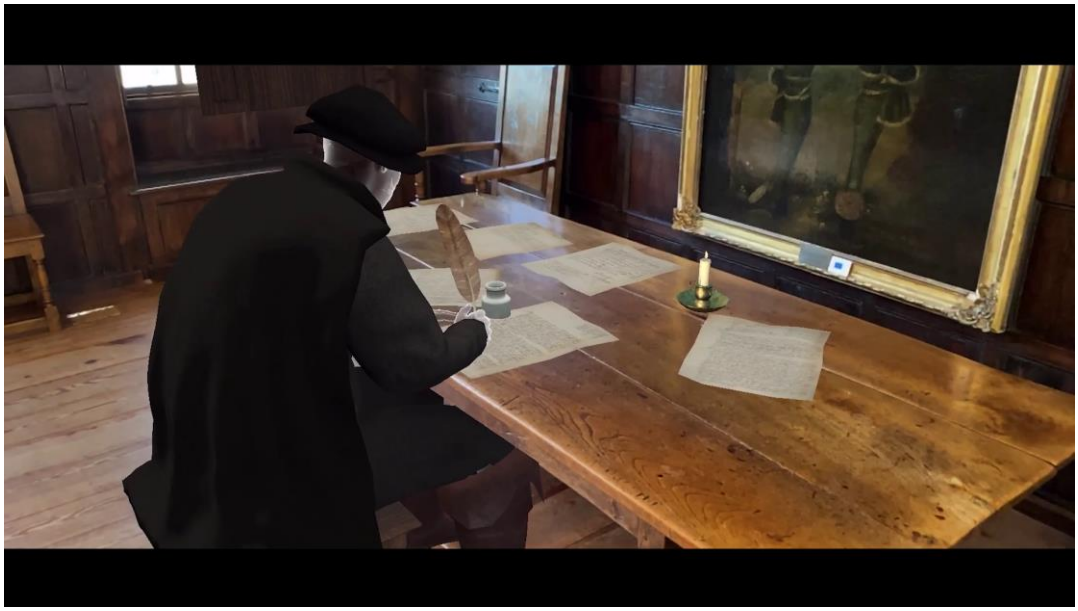

Fig. 5. A virtual Sir Ralph Sadlier sitting on a real desk and writing letters in candlelight (both virtual). Combined footage of real space and AR view.

Participants would either move around and explore or stay relatively still and absorb what they were experiencing. A few observed this difference themselves and juxtaposed it to the normal ways they behaved in a heritage site. They mentioned how one is expected to move in certain ways through the rooms whereas with this experience one could break this procession as each one has their own point of viewing what is presented through the glasses. About 60% of participants mentioned that they would have liked to be freer to explore the space, either the physical or the augmented, while they were going around with the glasses. Many did not realise that they could move freely and go closer to objects, and some retrospectively said that had they known, during the portrait and dance sequences, which were longer in duration than the rest, they would have turned around and explored instead of watching through. These comments suggest that there should have been a more detailed guidance when visitors are first introduced to the device and are briefed about the experience, or during the experience through the script.

3.2.2 Usability

Since it was not the focus of the PMM process, usability issues were not reflected on the maps but were discussed during the focus groups. Part of the evaluation concerned the use of the device by different age groups. None of the participants complained about the heaviness of the glasses, in fact everyone enjoyed the experience and they were disappointed that it ended relatively soon. The major disadvantage, which has been identified as a general issue for Hololens users, is the 'pinching' gesture they must make to move from chapter to chapter. For some participants it was difficult to form the shape in a position where the camera can see it, and this was observed irrespectively of age. (Krzywinska et al. 2020) addressed this issue by using physical objects connected to the Hololens headset. We could have used a similar approach, however, in their work, physical objects acquired meaning as they designed an escape-room style game in the museum and the objects were part of the mechanics of the game. Having an object just to click through chapters would always occupy the viewers' hands for a trivial task, and it would not be optimal for the experience. One thing I particularly aimed at evaluating was if the number of clicks on the visual cues to move from between sequences and chapter broke the experience. The hypothesis was that users wouldn't like having to click often but in fact everyone who was asked about this felt that the number of clicks was reasonable, and it worked well as a navigation tool. They would have felt lost without them. A few mentioned that they would welcome the opportunity to go back to each chapter and repeat it. Participants also said that another use of having the clickable spots visible in space would be that they may want to choose which stories they want to hear.

4 TOWARDS A FRAMEWORK FOR SMART GLASS AR HERITAGE EXPERIENCES

Despite the plethora of mobile AR projects in the past 20 years there have been only a few attempts to create frameworks for designing AR experiences, none of them for cultural heritage. (Irshad and Dayang 2016) proposed a framework for mobile AR based on work by (Olsson 2013). They base their framework on user-centered design considerations often met in product or service design. It consists of layers of the experience that should be taken into consideration starting from product/service features, time periods surrounding the experience and specific context of application. Earlier frameworks such as that of (Dunser et al. 2004) and (Gabbard and Hix 2001)

rely heavily on usability considerations. In my proposed framework I keep a user-centered design approach with consideration for usability, however, I include them in the framework rather than base its focus on them. The creation of the framework happened at the same time with the development and evaluation of Sutton House Stories by observing and evaluating the design process at a meta-design level. The transdisciplinarity of the collaboration allowed me to combine perspectives, identify each stakeholder's focus, and explore how the different viewpoints and goals can be integrated in a new methodology while the design and evaluation of the experience allowed me to identify key considerations for the design phase. The collected insights from the evaluation of the experience and its design process were clustered together to form the framework's design pillars (Table 1). There are three design pillars upon which I base an AR heritage experience: Interpretation, Affective Storytelling, and Technology Considerations. Interpretation refers to the curatorial guide as to the learning objectives for the visitors and how it guides the design of the stories including the chronology and the selection of archival material. Affective Storytelling concerns the design of the stories into the AR experience; the opportunities for affective, embodied meaning making of the history by the visitors. Technology considerations refer to the affordances of the device and the opportunities it has to support and enhance the storytelling, as well as the challenges that may or may not become opportunities. Key aspects of this pillar include navigation, choreography, and integration with the story. These three elements describe how to work with the device. Usability and ergonomics considerations subsume the framework. All three pillars are interconnected and decisions in one area affects the others, and they should all be taken into consideration simultaneously during the design phase.

Table 1 Design framework for AR smart glass experiences

Design Pillar	Design elements
Interpretation (I)	a. Learning objectives b. Time navigation c. Archival material
Affective Storytelling (AS)	a. Historical Empathy b. Narration c. Visitor's role d. Viewer on and off boarding e. Agency f. Embodied cognition
Technology Considerations (TC)	a. Navigation mechanism b. Choreography (sequences, pace, movement in space) c. Sensorial input (gestures, gaze, eye tracking, directional sound)

4.1 Interpretation

Interpretation plays a pivotal role in selecting the stories to be told and shaping the content of the narrative.

4.1.1. I.a. Learning Objectives

Each heritage site has their own strategic priorities in what they want to communicate to their audience and what their learning objectives are (I.a). This is the first step for creating the experience and setting the context. For example, the challenge in Sutton House was how to portray a rich history spanning four centuries in a house that changed roles many times, and that is almost bare of objects and furniture. It is important to note that the priorities may change as part of the transdisciplinary creation process while exploring the potential paths.

4.1.2. I.b. Time Navigation

Within this process the timeline of the narrative is also defined. Having a linear timeline is useful for the visitors who will follow all chapters and sequences in order (I.b). However, breaking the stories down into chapters proved to be useful for selective walkthroughs. In a future of wide adoption of AR smart glasses having chapters might be ideal for visitors who want to choose which era/incident/personal story or similar they want to experience.

4.1.3. Archival Material

During the creation of the holographic content, there is the opportunity to use material from the physical archives which are often hidden and unused giving them a new role as living archives of the place (I.c). The involvement of the museum educators and public historians is fundamental for the development of the stories, the way these are told to create empathy, sourcing material from the archive, and offering insights into the different audiences they reach and want to reach. Their close collaboration with AR designers and developers is crucial for the archives to surface as story elements in an emotional context.

4.2 Affective Storytelling

Affective Storytelling concerns the content, the kind of stories and the sequence in which they are told, if any, the characters, the narration, the virtual material and the way it is weaved into the physical space, and the interactions between visitors, space, content, and AR media. The connection between all these is set during interpretation and guided by the construction of historical empathy for the viewer.

4.2.1 AS.a. Historical Empathy

Historical empathy (AS.a) involves the learner's understanding and contextualisation of how historical characters thought, felt, made decisions, acted, and faced consequences within a specific historical and social context through cognitive and affective engagement with them (Endacott and Brooks 2013). It is constructed at both the cognitive and affective levels through three interrelated and interdependent endeavours: historical contextualisation, perspective taking, and affective connection (Endacott and Brooks 2013). The stories' structure coupled with any interactions that help the visitor navigate it is central to achieving this balance since it affects how people relate to historical facts, events, and the characters presented in a narrative.

Tools to assist with this process have been explored in related literature, such as the importance of spatial arrangement of objects in an exhibition or heritage site and the design of the visitor's walkthrough them (Basu and McDonald 2006), mnemonic bridging and the use of physical objects, practices of imitation and replication (Zerubavel 2012), and balancing multiple perspective narration (Bal and Boheemen 2009).

4.2.2 As.b Narration

The narration can be linear or nonlinear, told by one or different perspectives, being narrated by an agent related to the content or an anonymous character who is not part of the content (AS.b). One-person narration creates a more emotional engagement whereas multiple perspectives support a more cognitive approach (Stradling 2003). In Sutton House Stories the first-person voice acted narration proved to be fundamental to the successful animation of the space while the fact that the narration was firmly connected to the AR material made it an appropriate synergy for increasing participant empathy with the characters. The script plays a very important role in creating empathy and much attention must be given in the selection of words to edit out affective or suggestive language that may interfere with the visitors' own response to the unfolding stories (Bedford 2001). Much time was spent in editing the script as well as directing the voice-over actors. In the second chapter the soundscape of girls playing and running around and the headmaster's script included a desperate attempt to help the girls learn to dance. Such moments in the voice acting can increase immersion considerably and make the experience 'humane' as participants called it. The quality of the script and acting was recognised by many participants with one comparing it to a theatrical event in another historic house "*where there was lights and animatronics but it seemed very staged and weird, this is more honest somehow [...] the story has to be done well and the characters have to be good and engaging, but even just sound and somebody talking is pretty good*". In addition, the virtual material that was not connected to the stories but provided a virtual animated backdrop helped make the virtual world more meaningful and strengthen the immersion. Examples of this was the virtual fire with the crackling sounds on the physical fireplace, smoke coming out of the pipe of one of the men during the Church Institute era, and a burning candle at Ralph Sadlier's desk. According to one participant the fact that there was virtual material not necessarily connected to what the narrator said suggested an element of exploration that seemed to go outside a prescriptive experience path. They said about the soldier: "*It could have been that his photograph is the thing that is lying on the table with the others that you can go and look at yourself even if it's not something that is an additional kind of function, just something else that is there. You can figure it out for yourself, this idea that maybe you have discovered something on you own off-piste*".

Many participants commented on how the change in the atmosphere from chapter to chapter, signaled by the soundscapes and the narrators' personalities, drove them emotionally. In terms of design the choice of one or many dramatic arcs can be used to highlight aspects that are more important to interpretation than others (Naliuka et al. 2010). This observation reveals that it is important to consider the experience holistically in terms of atmosphere and narrative. (Skolnik 2012) writes that 'if our goal is interpretation, and the most natural mode of communicating is storytelling, then narrative is the architecture that both structures and conveys the intended meaning'. Narrative is constructed through the selection of stories and the intended interpretation and communication of history to the visitors. It is the underlying structure that ties the stories together in a meaningful pattern and its construction gives meaning to the whole situated experience. In Sutton House Stories we chose pivotal historic periods with different atmosphere to portray but also created a unifying narrative to tie them together that was present but not explicitly told until the end. In this way visitors realised the different 'lives' of the house and how it has been kept 'alive' so far by people and communities caring for it and using it for different purposes through the years. To achieve this narrative, we reversed the timeline in order to finish the experience circa 1590 with Sir Ralph Sadlier, who built the house, asking the viewer to look out the virtual window while he says: "*A lot of things have changed over the years...but my house and its stories are still here. Will you share them so they are not forgotten?".* This ending phrase both invites the visitor to reflect on the reason they visited the house

and is also a quiet plea for the house, applied to any heritage site, to keep being visited, shared and loved, keep having new stories and not be forgotten. Of course, as an ending it is also left to the interpretation of each visitor, however our aim was to conclude the experience offering the opportunity for what (Skolnik 2012) refers to as 'epiphany', the intuitive perception as the cumulative result of already received information happening in the moment and bringing about profound change – which also leads to learning.

4.2.3 AS. c and AS.d Visitor's Role and On-/Off- boarding

The design must consider the visitor's smooth transition across the different roles from visitor to viewer, interactor, explorer, and experiment with ways to integrate it with the narrative (AS.c). The framing of the role is important since *"participants may not necessarily be expecting an immersive experience as part of a heritage visit, or if they do, may have little idea what awaits them"* (Kidd 2018). Whether they are given a role or not, particularly important is how the visitors are introduced to the experience and how they leave it (AN.d), called the user 'on and off boarding', an area that hasn't been researched much in AR heritage design. As discussed, in Sutton House Stories we decided against giving the visitor a role. Still, the viewers must be given enough time to get accustomed to the new technology and this part ideally should be integrated into the narrative. In addition, the transition from the physical to the hybrid world and back must be designed to be smooth and meaningful. An example in VR is (Moseley 2019)'s suggestion to use 'portals', in a way similar to waiting lobbies, to give the VR viewer a glimpse of the environment they are about to enter.

4.2.4 AS.e Agency

Attention should be given to the different levels of agency that viewers will have on how the story develops, and the multiple ways they can interact with the content (AS.e). This is a rich area where the role of the creative writer and (digital) storyteller will be fundamental within the transdisciplinary collaboration. The focus groups showed that a level of empathy with the historical circumstances of each era was achieved not only due to the marginalised stories but also because of the agency the viewers were given to explore and act in the hybrid space. Agency can have different levels. In Sutton House Stories we focused on playful interaction which was integrated at points throughout the experience, such as trying out the minuet dance, and going closer over Ralph Sadlier's shoulder to read his letters. Visitors can be given more agency such as in heritage games (e.g. Krzywinska 2020) or having a multiple ending narrative (e.g.Malaka, Schneider and Kretschmer 2004), however, as mentioned before, there should be careful consideration of the balance between designed level of agency and situated, embodied learning. In this framework I suggest looking more at playful interactions within the embodied experience rather than focussing on creating a game since the latter is a complex and nuanced design process which can constitute a different framework in itself.

4.2.5 AS.f Embodied Cognition

Within the playful interaction discourse, discussions during the focus groups revealed that a closed loop between action and perception can strengthen the visitor's embodied understanding of the hybrid physical-virtual space (AS.f) and further add to the immersion of the viewer. Such moments happen, for example, when the viewer goes closer to a 3D character and the character turns towards them to talk, or they do something that causes the character to react (e.g., reshuffle Sir Ralph's letters on the desk). In a funnier take, in their attempt to pick up an object, viewers can push another causing a mess. Such moments make the brain couple the physical action with the

virtual reaction and, thus, lead to the perception that the hybrid space is momentarily the real one. In a similar manner, one participant mentioned how it would be nice if there were some physical props that would give you the visual information but only when you touch them. Such interactions were not designed in Sutton House Stories but were suggested by participants as areas for further development, especially since new devices will offer additional and better gestural interaction. This area is certainly a promising emerging research playground.

4.3 Technology Considerations

Technology Considerations refer to the limitation and opportunities of the AR device. As seen in the design process AR glsses have specific challenges that affect design decisions in the other two areas.

4.3.1 TC.a Navigation Mechanisms

Navigation mechanisms (TC.a) should include different options for the several types of visitors. Wearing AR glasses changes the body's kinesthetic perception so it is crucial to consider how the viewer will move around with it. This starts at the on-boarding stage. For example, a couple of participants mentioned that, because of the excitement of using a new technology, they took some time to get used to the visuals and did not pay much attention to the narration of the first chapter. This issue could have been addressed by allowing more time to each participant to familiarise themselves with the technology using an introductory scene. In the case where the viewer assumes a role, how the device works needs to be integrated into the narrative as mentioned in the on-boarding section under Affective Storytelling. Accordingly, the same set of considerations must be taken for off-boarding participants after the end of the experience. In terms of walking through the space, there should be an explicit assist together with the story elements to clarify where the viewer focuses next. In Sutton House Stories a visual arrow that provided a cue for turning towards the next point of interest, usually together with the narrator prompting them to 'turn around and look at' was of great help for orientation. Interestingly, some participants, who were used to playing video games, mentioned that they would have preferred the arrows to be of a different shape and smaller visual indicators of other places of interest in close proximity, not particularly the next one in order. In that way, navigation does not become sequential and guided but allows people to look at things in the order and way they want.

4.3.2 TS.b Choreography

Choreography (TC.b) involves the design of a coherent path between chapters, in the case these are played from start to end and finding creative solutions for when viewers take time to explore instead of following what unfolds in the hybrid space. Having chapters and sequences in the chapters accessed by the virtual pins was deemed a very appropriate way of traversing through the stories because it gave the opportunity for nonlinear engagement and replayability. One participant mentioned how directional sound can guide the user stating that the second they heard a bird sound they looked to the window, which was the next sequence. This would be one method of guiding the viewer. However, this may not be ideal for those who prefer or need scripted guidance so both can be present or selectable as options in the experience. These observations highlight the script and sound as important factors in creating the viewer choreography in the space.

It was interesting to observe how different participants spent different amounts of time at each sequence. Initially the script included gentle prompts by the narrator to proceed but in the end, it was decided that viewers should be able to go through the experience at their own pace. It proved to be a right decision as many participants would stay and look at the virtual material long after the narrator stopped talking.

Another observation was that almost half of the participants did not move much around the virtual material whereas the rest felt the need to move and explore further. Many of the latter mentioned that they didn't feel they had to interact or pay much attention to the virtual characters and they would rather look around and see if something else was happening. Sometimes this was triggered because the sequence was quite long, for example the dancing feet, and they would rather have heard more of the previous story instead. Others said that they were cautious to look elsewhere because of the fear of missing something out from the sequence. In order to allow them further agency in this, the narration and any animated visuals can stop at will, e.g. when the viewer's gaze is turned away.

Movement in space has several challenges when the user is in a small space together with many other visitors. If the viewer watches something in a distance and other visitors pass in front of them, they will, due to the lack of occlusion, obscure the view of any virtual material that is positioned in front of the passer by, and break the experience. This is a technology issue and the best way to address it currently is for the designers to acknowledge it and take it into consideration in creating the sequences. The viewers should also be made aware of it during on-boarding.

4.3.3 TC.c Sensorial Input

Finally, the opportunities for sensorial interaction that the technology affords (TC.c) should be used as tools to enhance affective narrative. These include sound, gesture and modalities that were not utilised in Sutton House Stories such as gaze and eye tracking. The combination of these tools with tools for creating historical empathy (AS.a), agency (AS.e) and utilizing embodied cognition (AS.f) open new avenues for creating embodiment, presence and meaning.

5 FURTHER RESEARCH

This article presented a prototype framework for designing affective smart glass AR experiences for heritage sites using AR smart glasses. The framework's design pillars can be used as design starting points in future applications. The pillars are not hierarchical and stakeholders can decide how much weight each design consideration will have in the overall composition depending on the project's production goals, parameters and limitations. What is paramount is the involvement of all stakeholders in co-design and decision making. The proposed framework is only a milestone in the process of identifying, understanding and addressing design problems in the creation of AR learning experiences in heritage sites. Areas such as the use of sensorial input, user on and off boarding, using the glasses outdoors at night time, accessibility, and inclusivity, require further research. Technology, which is one of the three design pillars of the proposed framework, is constantly advancing so issues that are important to address now may be obsolete in the future and new issues will arise, such as concerns over privacy. Technological advances will also bring new opportunities that will influence the design.

The transdisciplinary work upon which this framework was built reveals more than has been so far discussed in this paper. During the design process it was observed that heritage interpretation, normally the task of curators, historians and heritage educators, opens up to digital designers and to anyone involved with expanding the interpretation through digital means in-situ. The way the 21st century museums interpret heritage creates opportunities for new skill sets and roles in both the heritage and design industries that can drive innovation for the future. These will bring new opportunities to the design approach enriching the Interpretation pillar. Therefore,

this framework is given here as a live, expandable and adjustable base to be further developed as its design pillars change and readjust.

ACKNOWLEDGMENTS

This project was carried out under an Arts and Humanities Research Council Leadership Fellow grant (Grant Ref: AH/S005692/1). The author would like to thank the collaborators for the expertise and ideas they brought into the project as well as their commitment and enthusiasm: the Education and visitor experience team at Sutton House - National Trust (Sean Curran, Danielle Handley, Emma Gilliland, Katy Parry, Daniel Adediran, Patti Hague), Fracture Reality AR developers (Mark Knowles-Lee), Mnemoscene AR developers (Sophie Dixon), the volunteers at Sutton House who made the evaluations as smooth a possible, and the testers who helped improve the user experience and who, with their feedback, contributed to the framework.

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