HISTORY RE-EXPERIENCED

IMPLEMENTING MIXED REALITY SYSTEMS INTO HISTORIC HOUSE MUSEUMS

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To my family, to Liberia, to Africa, this is for you!

ABSTRACT

As immersive technologies have become ubiquitous today, traditional museums are finding success augmenting existing exhibits to increase visitors' satisfaction. However, due to the immutable nature of house museums, and its tendency to place visitors in direct contact with historical artifacts, museum managers are seeking original approaches to cultural preservation. Implementing mixed reality in house museums is one such approach. The goal of the study is to develop and test a conceptual framework that guides how designers can use the affordances of mixed reality systems to create experiences that align with the range of historical narratives found in house museums. Such experiences can contribute to improving visitor's satisfaction, self-interpretation, and understanding of the homeowner's life and the community within which they lived. Building on user-centered design methods, the researcher developed and tested an augmented reality (AR) mobile application centered on the Pope House Museum in Raleigh, NC. The outcome of this research suggests that house museum visitors should have agency in deciding the lens through which they experience the variety of historical narratives present in the home.

TABLE OF CONTENTS

AREA OF INVESTIGATION

PROBLEM SPACE

At the intersection of history, home and museum stands historic house museums. Viewed as instruments of communication, (Pinna, 2001) house museums are invaluable social and cultural apparatuses (Young, 2016) through which visitors can experience history in the living environment of a home. Giovanni Pinna, former chairman of the International Committee for Historic House Museums, attributes the significance of these historic sites to their ability "to evoke history and put the visitor into direct contact with it" (Pinna, 2001). To continue a legacy as a source of living history, house museums bear the responsibility of remaining immutable in a changing society. But the unchanging ethos of preserved historic homes (Young, 2016) and the impossibility of manipulating its meaning (Pinna, 2001), makes it difficult for house museums to adapt to the needs and desires of today's visitors that seek a pleasant experience with family and friends (Young, 2016). As a result, museums managers are finding difficulties responding to visitors' interest and generating adequate revenue needed to keep the doors of house museums open. "It is a major challenge of institutional survival for many house museums to entice sufficient paying visitors to maintain their operations" (Young, 2016). Furthermore, the educational lens through which curators present the history present in the home, is only one of several motivating factors that bring visitors to these historic sites.

While museum officials often present visitation to house museums as an educational activity, market research shows that educational value is only one of several conditions that contribute to visitors' satisfaction (Young, 2016). Entertainment, enjoyable experience, and escapism are other key aspects (He et al., 2018). However, as traditional museums are turning to mixed reality systems and other contemporary apparatuses to increase the entertainment value of exhibitions, the in-situ nature of house museums raises new challenges during the implementation of modern technologies in historic homes. Because house museums reflect the atmosphere of a historic era (Risnicoff de Gorgas, 2001), implementing technology foreign to the period represented within the home can take away from the authenticity of the artifacts present in the home. Therefore, museum managers primarily rely on tour guides and original artifacts in the home to educate and serve as sources of entertainment for visitors. But in today's technology driven society, a limited approach to enriching the house museum visitation experience cannot compete with traditional museums that are turning towards mixed reality systems to increase visitor's satisfaction.

The final factor stalling the growth of house museums is the authoritative approach through which museum officials present visitors with the historical narratives found in the home. For efficiency, museum managers often script and control the house museum visitation experience (Young, 2016), giving limited opportunities to visitors to arrive at their own interpretation of the narratives present in the home (Baker, 2017). However, if a goal of house museums is to bridge personal connections between visitors and the home (Pinna, 2001), historic houses must become an interpretive environment that encourages imagination, discovery and reflection. In the Ph.D. dissertation, *Repurposing Museum Interpretation in American Historic House Museums*, Dr. Lesley Barker asserts that if the house museum is to remain relevant, it must "shift its interpretive role and practice from knowledge broker and expert to become an interpretive space" (Baker, 2017). House museum visitors should receive information in a way that enables them to reflect on their own lives through active interactions with the material and immaterial cultural artifacts present in the home.

Lesley Aileen Pendleton Barker
Repurposing Museum Interpretation (2017)

[house museum] has the potential to shift its interpretive role and practice from knowledge broker and expert to become an interpretive space.

JUSTIFICATION

Immersive technologies such as virtual reality (VR), and mixed reality (MR) systems have become ubiquitous tools used by universities, heritage sites, nonprofit organizations, and businesses for educational and training purposes. Traditional museums are harnessing the power of augmented reality to overlay digital information over physical artifacts to increase visitors' satisfaction and willingness to pay more for experiences (He et al., 2018). VR's ability to immersive participants into real-life scenarios has made it a go-to tool for job training simulations (Mastli et. al, 2017). Using head mounted displays (HMD) and peripheral devices such as hand controllers, VR immerses participants in computer-generated digital environments that can be experienced as if such environments were real (Jerald, 2016). Colleges are also using VR's empathy driven capabilities to increase student's cultural competency and social aptitude (Dawson et. al, 2017). The immersive potential and digital affordances of mixed reality systems provide new opportunities for museum managers and designers to re-imagine the house museum visitation experience.

Research done at Temple University by Zeya He and her colleagues suggest that within the context of museum experiences, "aesthetic appreciation is a highly personal experience requiring individuals' self-driven comprehension and mental imagery (He et al., 2018).

Instead of relying primarily on docents, museums can implement mixed reality experiences to complement guided tours. The system can also shift the role of docents from knowledge broker to mediators and catalyst that provide context to situate visitors within the historical narratives present in the home.

An augmented reality application can enhance the museum visitation experience by providing an additional lens through which visitors experience the possible history present in the home—increasing visitors' participation, self-reflection, and self-interpretation. Furthermore, a complementary augmented reality experience can play an essential role in communicating the immaterial culture of the home through the implementation of dynamic informational cues. With limited spaces and resources available in the house, showing multiple artifacts to communicate the historical significance of the home can be a challenging task for curators. By developing a practical approach of implementing mixed reality systems in house museums, designers can create location-based digital environments that allow visitors to simultaneously experience multiple narratives of the history present in home.

RESEARCH CONTEXT

Pope House Museum

In his PhD dissertation, *The House That Dr. Pope Built*, Kenneth J. Zogry (2008) provides an historical documentation of Dr. Pope's life, family history, and contribution to African American struggle for civil rights in North Carolina. Zogry's dissertation also documents his collaborative initiative with the Pope family's charitable trust that placed the house on the National Register of Historic Places in December of 1999, despite prior discussions of using it for office spaces. A goal of this investigation is to contribute to the preservation of the Pope House Museum, the only historic home built and occupied by a African American family in North Carolina (Zogry, 2008).

Figure 1: *Historic photo of the Pope family*

Dr. Manassa Thomas Pope was one of Raleigh's most prominent African American homeowners during the nineteenth century. A physician and political figure in the prestigious Third Ward of Raleigh, Dr. Pope built his family's home in 1901 on the 500th block of South Wilmington Street. It was here at his home, known today as the Pope House Museum, that Dr. Pope lived with his wife, Delia, and two daughters, Ruth and Evelyn Pope. Dr. Pope died in 1934 at the age of 76. Delia continued to live in the house until her death in 1955.

Ruth and Evelyn lived long and successful lives after their parents' death. The Pope daughters moved back to their childhood home in the 1970s after retiring from their respective careers. Back at the Pope House, the sisters created the Evelyn B. and Ruth P. Pope Charitable Trust with their assets shortly before Evelyn's death in 1995. After her sister's death, Ruth moved into a nursing home where she died in December of 2000. The trustees of the Charitable Trust founded the nonprofit Dr. M. T. Pope House Museum Foundation in December of 1999. Now owned and ran by the City of Raleigh, the Pope House Museum currently stands amidst several city skyscrapers and businesses as a lone reminder that the Third Ward was once a thriving African American community.

Figure 2: *Present-day exterior photo of the Pope House*

Figure 3-4: *Historic exterior photos of the Pope House*

RESEARCH QUESTIONS

Primary

How can the design of mixed reality systems be implemented in historic house museums to increase the experiential value of a visit?

Subquestions

How might the system incorporate design elements to expound upon the narrative of material artifacts present within the home?

How might the system bridge a connection between the history within the home to the broader historical narrative of the community within which the homeowner lived?

How might the system adapt to the specific needs and interests of visitors and enable them to customize their visitation experience?

DEFINITION OF TERMS

Historic House Museum

A small genre of museums established to recognize the heroic character of an inhabitant, and to promote the national and civic identity of a historic period (Young, 2018).

Experiential Value

Experiential value is based on the transaction or co-creation of experience between the service provider (i.e., museum) and the customer (i.e., visitor), particularly interactions involving direct either usage or distant appreciation of goods or services (Wu & Liang, 2009).

Mixed Reality

a subset of Virtual Reality (VR) related technologies that involve the merging of real and virtual worlds somewhere along the virtuality continuum which connects completely real environments to completely virtual ones (Milgram & Kishino, 1994).

Design Elements

Information type consisting of visual and verbal cues (He et. al, 2018), through which a visitor might interact with a digital object or scenery.

Narrative

a way of presenting or understanding a situation or series of events that reflects and promotes a point of view or set of values (Webster dictionary, 2019).

Material Artifacts

[a physical object] characteristic of or resulting from a human institution, period, trend, or individual (Webster dictionary, 2019).

Visitation Experience

Events, physical activities and social engagements that visitors take part in during visitation to a house museum.

Docent

a person who leads guided tours especially through a museum or art gallery (Webster dictionary, 2019).

ASSUMPTIONS & LIMITATIONS

Assumptions

This research investigation makes the following assumptions. Museum managers will acquire mixed reality systems and resources needed to implement the technology within house museums. Museum visitors will take part in training needed to use mixed reality devices and participate in immersive experiences.

Limitations

The researcher established the following limitations to ground the scope of the investigation. Devices used to develop the prototypes are those the researcher had access to or could acquire within the timeframe allotted for the investigation. While the researcher recognizes the importance of designing for inclusivity, demographics considered during the investigation are people with full hearing, vision, and mobility. Visual cues, verbal cues, and tactility (Figure 5) were the only mixed reality design elements considered during the development of the prototype.

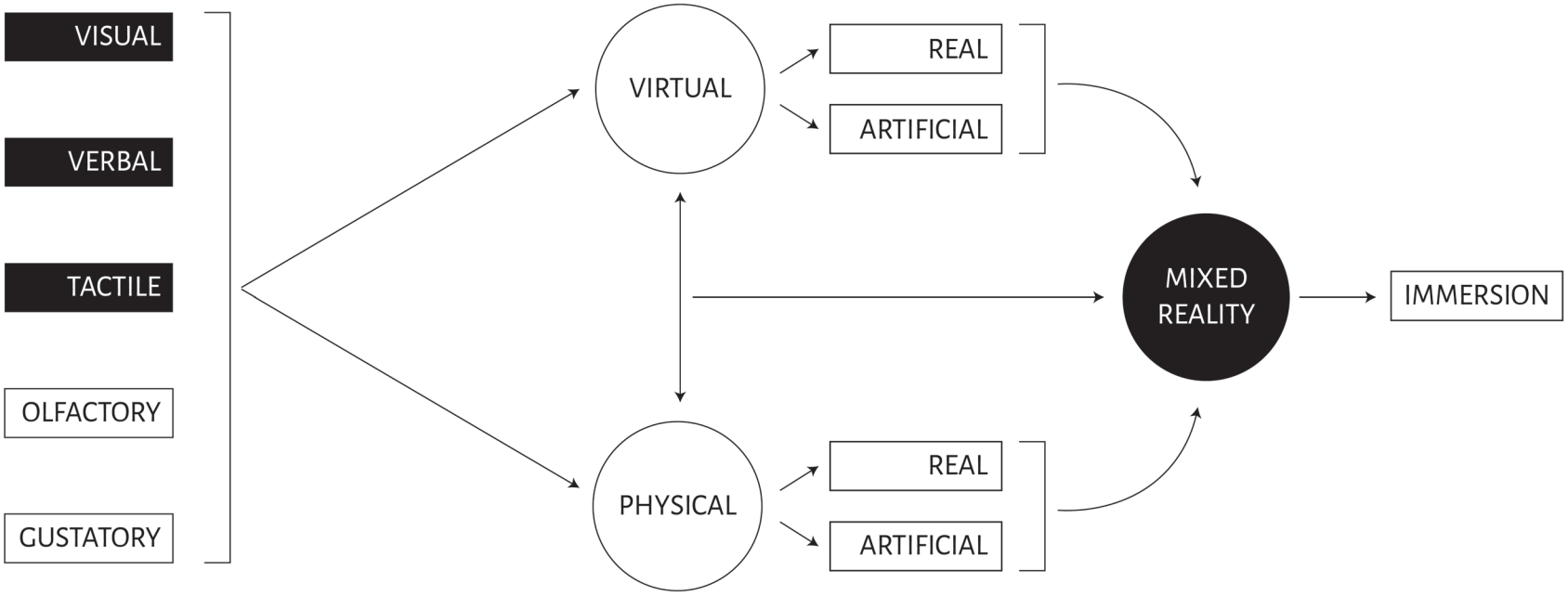


Figure 5: *Perception of Mixed Reality Diagram highlighting sensory cues considered for this research investigation*

LITERATURE REVIEW

This section provides a synopsis of relevant literature situated within three domains: House Museums, Mixed Reality Systems, and Experiential Value.

HOUSE MUSEUMS

Introduction to Historic House Museums

Giovanni Pinna (2001)

Giovanni Pinna, historian and former chairman of the International Committee for Historic House Museums, attributes the significance of house museums to their ability "to evoke history and put the visitors into direct contact with it." He suggests that house museums communicative power is rooted in its ability to transfer historic information through real artifacts. He asserts that because exhibited artifacts within the home are real, visitors believe it is impossible to manipulate the meaning of house museum artifacts. However, Pinna acknowledges that visitors' belief that the exhibited artifacts are void of manipulation strengthens the museum's authoritative approach to interpreting the historical narratives present in the home. He states that the museum's authoritative approach to communication history makes house museums a powerful instrument of political indoctrination.

Historic House Museums in the United States and the United Kingdom: A History

Linda Young (2016)

Professor of Museum Studies at Canberra and Deakin University in Melbourne, Linda Young, suggest that house museums stand as a representation of a nation's cultural and social identity. While there are greater similarities between house museums and other genres of museums than there are differences, Young attributes the idiosyncrasies of house museums to their dual purpose as a museumized object and a home. She describes museumization as the process of transforming a house into a museum. As a museumized object, visitors view the house and the objects contained within it as a specimen. As a home, the house museum embodies personal, social, and cultural narratives of the homeowners and the communities within which they lived. Perhaps Young's finest contribution in her book is the classification of house museums into six distinctive categories. She based her matrix of distinguishing the types of house museums based on the motivations upon which the home was museumized. Young suggests that the categories are not incontestable but creates an organized system for analyzing house museums. Below are Young's taxonomy of house museums:

Hero Houses are houses of nationally recognized historic figures

Artwork Houses are houses preserved for the sake of their interior or exterior design quality.

Collectors Houses are houses that have collected antiquities and art that have a deep connection to the house itself.

Social History Houses preserved because they represent the lifestyle of the non-elite within a society.

Country Houses pertains particularly to the United Kingdom, these are palaces and aristocratic homes.

Not-very-important Houses are imitations of these other species that are museumized without much justifiable significance.

House museums are smaller (10 -15% of all museums) in comparison to other genres of museums, thus, little evidence is known about the visitors and visitation experience to these historic sites. According to Young, museum officials ritualize and control the house museum visitation experience more so than other genres of museums. She likened the visitation to house museums to that of a pilgrimage. "The visitors experience the house as a special, even sacred, place" she writes. A controlled visitation experience gives little room for self-reflection and self-interpretation, decreasing the experiential value of a visit. Therefore, Young suggests that house museum staff plan visitation experiences that maximize visitor's satisfaction. "Failing house museums achieve proved reluctant to bite the bullet of adapting to another function, even in very straightened times" she concludes.

Reality as Illusion, the Historic Houses that Become Museums

Mónica Risnicoff de Gorgas (2001)

Mónica Risnicoff de Gorgas describes the atmosphere of the historic house museum as a place that invoke intrinsic feelings and memories in visitors more so than any other genre of museum. According to Risnicoff de Gorgas, former director of the Virrey Liniers Casa Museo Histórico Nacional in Argentina, the atmosphere of the house museum immerses visitors into historical periods and increases their curiosity about the individuals that once lived in the home. "[Visitors] cannot help wondering if the people who used to live in the house at times felt the same joys and sorrows they themselves have felt," she writes. A visit to a house museum also provides an opportunity for visitors to reflect on their own lives. Risnicoff de Gorgas states that visitors regard the house museum as a time machine which offers a possibility for them to connect with the past and learn about not only who they are, but also who they are not. She suggests that "[House Museums] produce an intimate link between collective memory and personal memory." Therefore, unlike other genres of museums, house museum has the unique ability to generate a combination of cultural images to convey feelings-perceptions and communicate information to visitors.

Mónica Risnicoff de Gorgas
Reality as Illusion (2001)

[Visitors] cannot help wondering if the people who used to live in the house at times felt the same joys and sorrows they themselves have felt.

RelicPad: A Hands-On, Mobile Approach to Collaborative Exploration of Virtual Museum Artifacts

Steven Neale, Winyu Chinthammit, Christopher Lueg, and Paddy Nixon (2013)

Neale et al. explores how museum curators researchers can use a mobile application to analyze virtual museum artifacts and facilitate collaborative discussion remotely. The researchers suggest that the ability to physically handle museum artifacts is a powerful and informative learning experience. Handling an artifact provides vital spatial information and physical understanding of the artifact. Due to the fragility of museum artifacts, they are often off limits or enclosed

in display cases. Therefore, the ability to physically handle the artifacts are not always a possibility. The researchers created a tested a case study that provided an alternative to physically handling museum artifacts (Figure 6). Using RelicPad, the researchers constructed a virtual 3D model of a museum artifact that participants could interact with digitally. Digital interactions of the artifact included the ability to rotate and scale the object and leave real-time marking of interest points. The result suggested that RelicPad "facilitated exploration and collaborative discussion of the virtual museum artifact." The researchers also found that touch interaction techniques (the ability to rotate and scale the virtual artifact) made users feel in control of the manipulation of the virtual artifact as they would with a physical museum object.

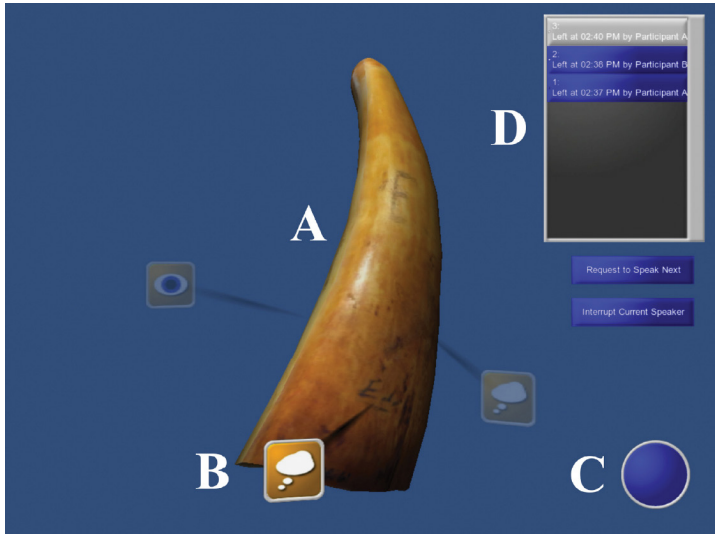


Figure 7: *RelicPad Interface*

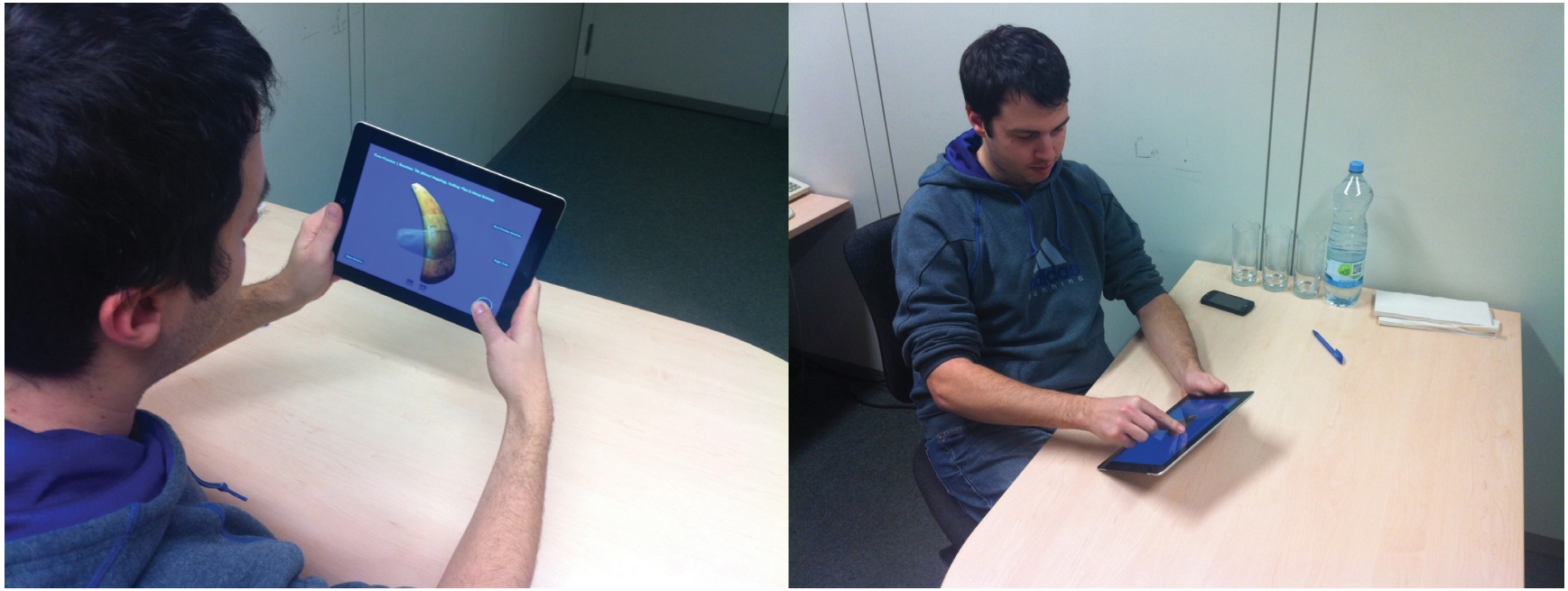


Figure 6: *Participant interacts with a virtual model on the RelicPad during a usability test*

MIXED REALITY SYSTEMS

Designing, Arranging, and Assessing Augmented Places through Mobile Media Alignment

Brett Oppegaard (2017)

Brett Oppegaard, an Associate Professor at the University of Hawaii, proposed the Mobile Media Alignment, a framework that serves as a conceptual guide for designing user-centered augmented reality experiences. Oppegaard suggests that designers put the framework in practical use and create experiences that effectively aligns digital experiences over physical environments based on location, spatial environment, and context awareness of users. According to Oppegaard, the three-tier guidance system, "is an idea that could lead people, especially designers and users, toward a new perspective on augmented reality and augmented places it can create." Below are descriptions of each tier of the Mobile Media Alignment framework:

Location Alignment creates the conditions under which interaction occurs and provides the context from which information is interpreted and incorporated into use.

Spatial Alignment is a recognition and awareness of everything physically nearby the user yet outside of the direct perceptions.

Contextual Alignment refers to the precise matching of experiences to user's needs in the specific context of the user and in customized configurations.

A Taxonomy of Mixed Reality Visual Displays

Paul Milgram and Fumio Kishino (1994)

In this article, Milgram and Kishinio proposed a taxonomy for categorizing and distinguishing different mixed reality displays. The authors define Mixed Reality as "a particular subset of Virtual Reality (VR) related technologies that involve the merging of real and virtual worlds somewhere along the virtuality continuum." The virtuality continuum begins with the real environment and ends with the completely virtual environments on the opposite extremum (Figure 8). The real environment refers to the world around us. Virtual environments refer to synthetic worlds that may or may not replicate elements from the real world into virtual experiences.

Situated between the real and the virtual world are augmented reality (AR) and augmented virtuality (AV), two subsets of mixed reality experiences. Augmented reality are experiences that incorporates digital cues to augment real environments. Conversely, Augmented Virtuality experiences bring elements from the real world into virtual environments. The authors note that as technology advances distinguishing AR from AV experiences may become less straightforward. Therefore, they proposed that the broader term, mixed reality, can cover the gray area in the center of the continuum. The authors also refers to the term Hybrid Reality (HR) to describe an encompassing concept that blends multiple displays.

EXPERIENTIAL VALUE

When Art Meets Tech: The Role of Augmented Reality in Enhancing Museum Experiences and Purchase Intentions

Zeya He, Laurie Wu, and Xiang (Robert) Li (2018)

In 2018 He et. al, researchers at Temple University conducted an experimental study to understand how augmented reality could increase tourist willingness to pay more (WTPmore) for a museum experience. Building upon the mental imagery theory and the attention control theory, the researchers tested two AR design elements (dynamic visual and dynamic verbal cues) and their role in increasing museums experiential value and subsequently influencing tourist behavior (Figure 9). In product advertisement, verbal cues are a text description of a product. By contrast, visual cues related to a pictorial representation of the product. The results of the study confirm all hypothesis tested by the researchers, suggesting that dynamic verbal cue has a greater impact on increasing visitors' satisfaction and willingness to pay more for augmented reality museum experiences.

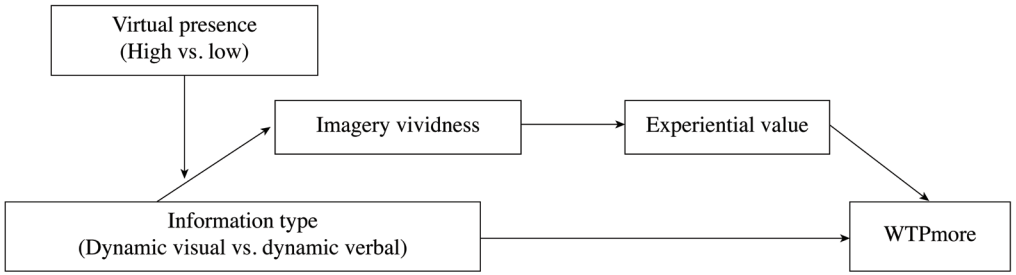


Figure 9: *Model demonstrating the effect of information type and virtual presence level on willingness to pay more*

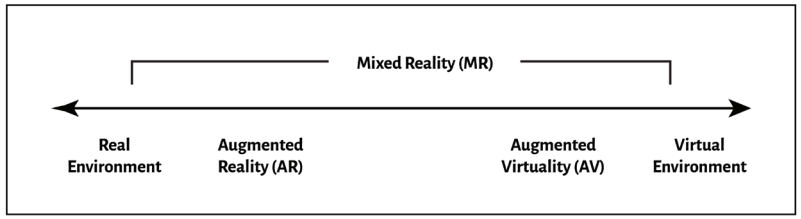


Figure 8: *The Virtuality Continuum adapted from Milgram et. al (1994)*

Introduction to Consumer Value

Morris B. Holbrook (1999)

Morris B. Holbrook, professor Emeritus of Marketing in the Graduate School of Business at Columbia University, defines consumer value as "an interactive relativistic preference experience." He states that, consumer value takes place when a subject (consumer) evaluates an object (product or service). In this chapter, Holbrook provided a framework for distinguishing eight key types of consumer value that he suggests researchers should considered when analyzing consumption-related behavior. The eight values proposed by Holbrook are: efficiency, excellence, status, esteem, play, aesthetics, ethics, spirituality. Holbrook later proposed the Typology of Consumer Value— a conceptual framework, made of three key dimensions, for categorizing the eight consumption experience values. These include: (1) Extrinsic versus intrinsic value; (2) Self-oriented versus other-oriented value; and (3) Active versus reactive value. Though presented as dichotomies, Holbrook suggest we view the dimensions as a continuum, each set positioned on one extreme to the other.

Experiential Value: Conceptualization, Measurement and Application in the Catalog and Internet Shopping Environment

Charla Mathwick, Naresh Malhotra, and Edward Rigdon (2001)

Building upon Holbrook's (1999) Typology of Customer Value, Mathwick and her colleagues developed a framework known as the experiential value scale to evaluate the retail shopping experience. The researchers states "Experiential value perceptions are based upon interactions involving either direct usage or distanced appreciation of goods and services." They argue that quality and price are not the only attributes that influence consumption behavior despite traditional empirical suggestions. Functional, conditional, social, emotional and epistemic utility are among key attributes Mathwick et. al argues have a greater impact on consumption behavior in comparison to quality and price. As suggested by Holbrook, the self-oriented experiential value taxonomy devised by Mathwick and her colleagues uses four quadrants to visualize two sets of dichotomies. The Typology of Experiential Value places the extrinsic/intrinsic values on the Y-axis of the quadrant and active/reactive values on the X-axis (Figure 10). Below is a listing and description of the four attributes used to label attribute of the experiential value taxonomy:

Consumer return on investment comprises the active investment of financial, temporal, behavioral and psychological resources that potentially yield a return.

Service excellence reflects an inherently reactive response in which the consumer comes to admire a marketing entity for its capacity to serve as a means to a self-oriented end.

Aesthetics Response is a reaction to the symmetry, proportion and unity of a physical object, a work of poetry or a performance.

Playfulness relates to the intrinsic enjoyment that comes from engaging in activities that are absorbing, to the point of offering an escape from the demands of the day-to-day world.

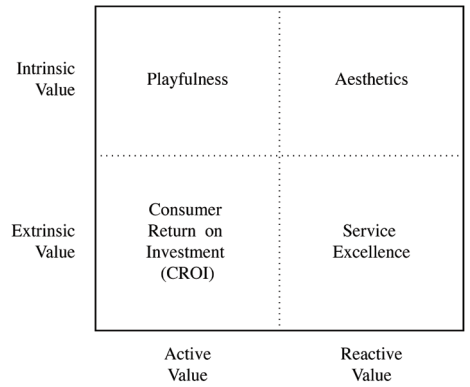


Figure 10: *Typology of Experiential Value*

Mathwick et. al
Experiential Value (2001)

Experiential value perceptions are based upon interactions involving either direct usage or distanced appreciation of goods and services.

CONCEPTUAL FRAMEWORK

This section provides an overview of attributes adapted from each framework used to develop the conceptual matrix. Refer to the literature review section for a synopsis of the research papers from which I adapted the frameworks.

VIRTUALITY CONTINUUM

The Virtuality Continuum is a framework developed by Paul Milgram and Fumio Kishino to categorize different mixed reality displays. The authors identified six classes of mixed reality display environments they used as a metric for distinguishing the various subsets of MR experiences.

I explored the various forms of experiences along the virtuality continuum during initial studies, but the final investigation focuses only on the use of augmented reality and hybrid reality displays (Figure 11). Of the six mixed reality classes, the term augmented reality refers to class 1, 2, 3, and 4 displays, while hybrid reality refers to class 5 and 6 displays (Milgram and Kishino, 1994).

For this investigation, I define augmented reality as cases in which two information types, visual and verbal cues, (He et. al, 2018) augment a real environment using See-through AR displays (Milgram et. al, 1995). Whereas hybrid reality is not explicitly located on the virtuality continuum, I refer to it as the interaction between virtual and physical artifacts within the home and the utilization of peripheral devices to invoke a higher level of immersion and interactivity. This definition therefore places hybrid reality in the grey area between augmented reality and augmented virtuality on the Virtuality Continuum.

Figure 11: *The Virtuality Continuum highlighting the two forms of Mixed Reality displays adapted to create the conceptual matrix*

EXPERIENTIAL VALUE TAXONOMY

The experiential value taxonomy is a system for categorizing key attributes that influence consumption behavior. This investigation excludes the extrinsic value dimension from the conceptual framework and considers only intrinsic, active, and reactive values. This is because this research primarily focuses on the types of mixed reality experiences used to enhance the museum visitation experience and places less consideration on the actual devices (mobile phone, head mounted displays, etc.) used to view the experiences. Therefore, playfulness and aesthetics response are the two attributes adopted from Mathwick et. al experiential value taxonomy and Holbrook's Consumer value framework (Figure 12). For this investigation, I define both playfulness and aesthetic values as self-oriented experiences (Holbrook, 1999). The differentiating factors between playfulness and aesthetics is that play involves an active engagement within an activity (Mathwick et. al, 2001), whereas aesthetics refers to an appreciation of the design or beauty of the experience (Holbrook, 2005).

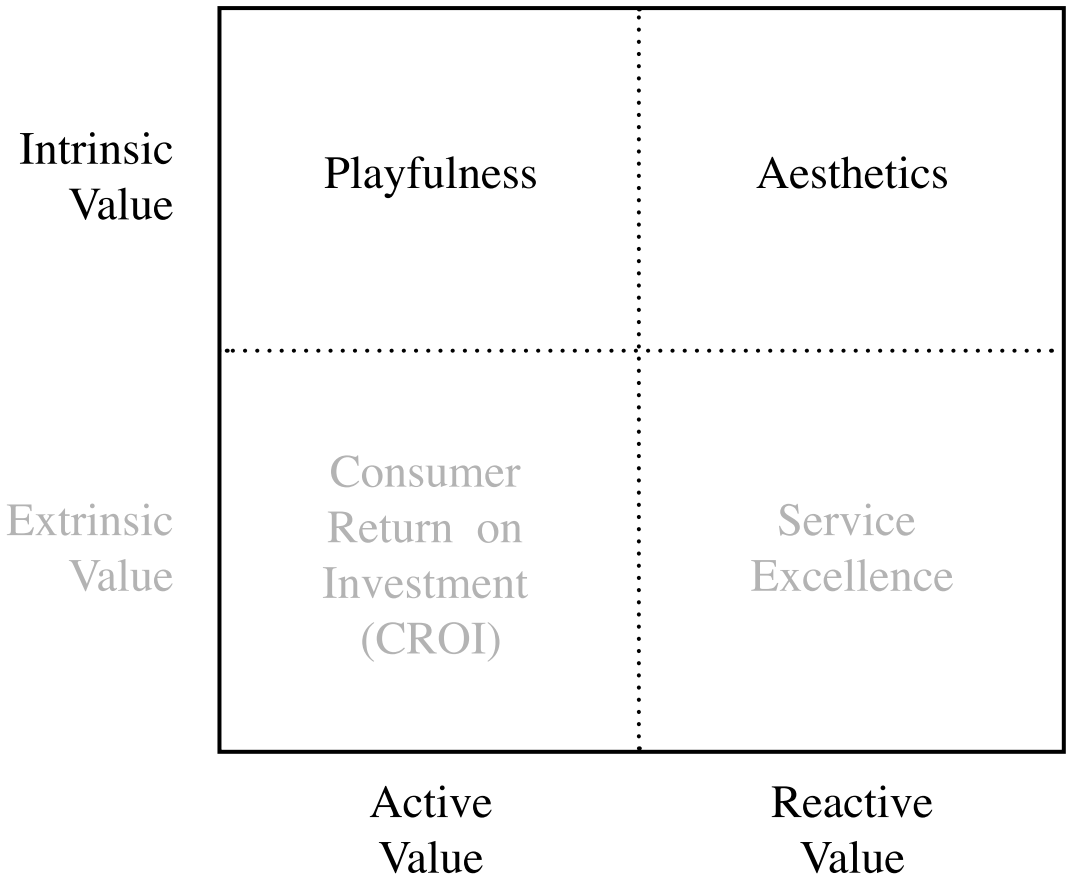


Figure 12: *Typology of Experiential Value highlighting attributes adapted to create the conceptual matrix*

MOBILE MEDIA ALIGNMENT FRAMEWORK

While the term Mobile may suggest that the framework is applicable only to AR experiences accessed on a smartphone, it's application is far broader. Mobile, for the purposes of this investigation, refers to the movement of the user from one place of interaction to the next. Mobile also connotes the transition from a purely physical environment to an augmented reality place.

Media or the communicative element of the framework encompasses the digital experience that is overlaid on the physical environment. For example, in the context of a house museum, digital media may include an audio description of an artifact or an augmented scene of virtual avatars interacting with real-world objects. This investigation therefore refers to Media as visual, auditory and haptic input and out channels through which information is transferred and received.

Alignment takes place at the overlapping where a virtual environment intersects a physical place (Oppegaard, 2017). Oppegaard describes alignment as "aligning content in various forms that connect and contrast with the user's perceptions and needs." Oppegaard acknowledges other forms of technical alignment needed for augmented reality experiences, such as object tracking, but states these are fixable problems.

This investigation adapts all three tiers (location, spatial, and conceptual alignment) of Brett Oppegaard' Mobile Media Alignment Framework. I situated each sub-question of the research investigation into a tier of the Mobile Media Alignment Framework. My conversation with Oppegaard at the initial stages of the research informed the development of the conceptual matrix and challenges that may arise when adopting the Mobile Alignment Framework for use within house museums.

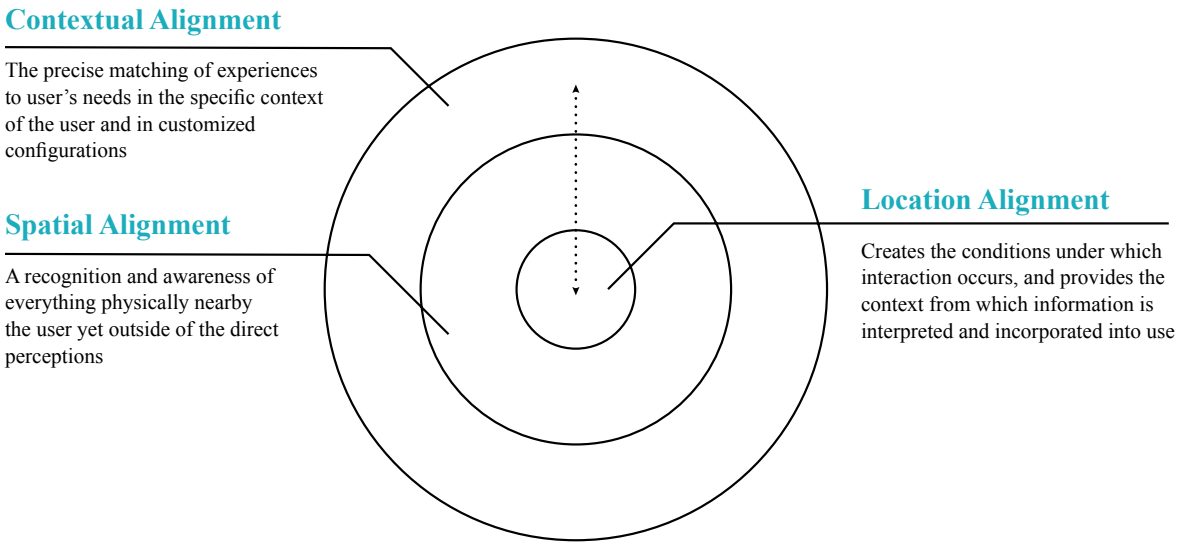


Figure 13: *Mobile Media Alignment Framework*

I combined the Virtuality Continuum, Mobile Media Alignment framework, and the Experiential Value taxonomy to create a conceptual matrix that informed the design studies of the mixed reality application.

CONCEPTUAL MATRIX

Table 1: Conceptual Matrix

	Augmented Reality (AR)		Hybrid Reality (HR)	
Location Alignment				
Spatial Alignment				
Contextual Alignment				
	Playfulness	Aesthetic	Playfulness	Aesthetic

RESEARCH METHODS

OVERVIEW

Observational Study

The primary focus of the observational study was to understand how docents guide visitors through the museum. A secondary focus of the study was to understand how visitors moved through the museum and interact with the artifacts present in the home. I used a semi-structured observational approach in which I occasionally participated in the tour with the visitors. At times, I also observed the visitors and docents' interactions from afar.

Interviews

I spoke with Ernest Dollar, Director of the City of Raleigh Museum, and Edna Ballentine, a former caretaker of the Pope House, to understand their unique perspectives and involvement with the museum. I also spoke with visitors to understand their motivations for coming to the Pope House. The interview approach was unstructured, allowing for flexibility in conversations with the interviewees.

Personas & User Journey Maps

Based on the information gathered from the observational study at the Pope House Museum, I developed personas of visitors to situate my explorations and ground my investigation using a user-centered design approach. The journey map articulates how docents guide visitors during a visitation tour before the implementation of the mixed reality system. During the development of the prototype, I revised the journey to show how the implementation of the mixed reality system would change the museum visitation experience.

Precedents

To understand current and emerging uses of mixed reality systems, I looked at AR and VR usage within and outside of the museum context. I analyzed the means through which visitors and participants access each experience. From the analyzes, I drew key functionalities of each experience most applicable to the implementation of mixed reality systems in house museums.

Prototype & User Testing

I developed a functional prototype of an augmented reality experience for the Pope House Museum. The experience enables visitors to experience the Pope family history based on their individual interests and motivation for visiting the museum. During the development of the prototype, I tested the experience at the museum to better understand how the system can adapt to the needs and interests of visitors. User testing was also essential to understanding which elements of the experience were the most successful and challenging to implement based on various conditions within the museum.

PRECEDENTS

England Originals

England Originals is an augmented reality mobile application that allows tourists to interact with the country's heritage sites before or during their visit to England. Before their visit, tourists can explore 6 itineraries, encompassing 16 historic cities, on the app's Tabletop mode. During Tabletop exploration, participants can click on historic landmarks for a brief description of each location. After exploring a city, participants may continue the tour to the next heritage site without returning to the home menu. The second mode, Portal, allows tourists who are physically present to interact with AR design elements that provides contextual information about each heritage site they visit. The app uses GPS tracking and smartphone camera to overlay digital information on buildings and other physical artifacts. At the different heritage sites, historical figures such as William Shakespeare also serve as virtual tour guides.

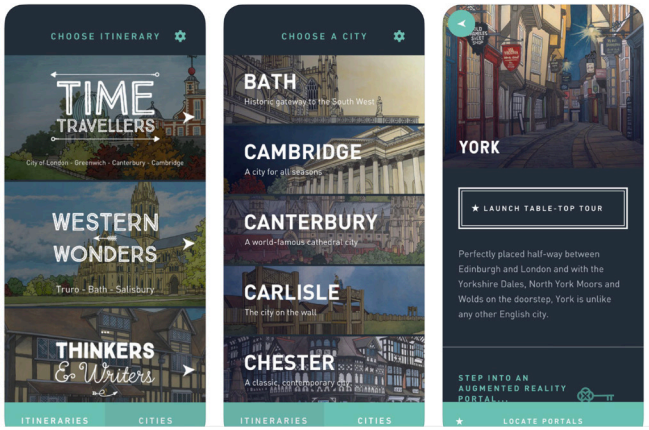


Figure 14: *England Originals interface*

Terracotta Warriors of the First Emperor

The Terracotta Warriors of the First Emperor exhibition, at the Franklin Institute in Philadelphia, uses augmented reality technology to allow visitors to place digitally recreated weapons into the hands on the historic clay statues. Archaeologist discovered the 8,000 plus clay soldiers that make up the exhibition beneath a Chinese persimmon orchard in 1974 (Hurdle, 2017). When the buildings that kept the statues, the wreckage destroyed the original weapons the clay soldiers once held. Designers created digital models of the soldiers using a technique called photogrammetry. Photogrammetry is the process through which hundreds of photos of a physical artifact stitched together creates a digital model of the artifact. The implantation of augmented reality within the exhibition provide visitors with a lens to see a digital model of the weapons in the clay soldiers' hands. Museumgoers can download the AR application upon arriving at the museum and interact with the statues by pointing their device camera at trackers placed next to each soldier. When the recreated weapons appear on the visitor's phone, they can manipulate it shapes and color to see various features of each type of weapon.

Figure 15: *(above) Visitor interacts with the Terracotta Warriors AR experience*

CONT...

The VOID

The VOID is a location-based, hyper-reality experience that immerses visitors into virtual worlds mapped onto a physical environment. A leading company in the field of location-based VR entertainment, the VOID currently has 11 locations nationwide. At each location, visitors can choose one of four movie-themed worlds to experience with their friends and family. In addition to the 360 visual and audio sensation in-home VR systems can produce, participants in the VOID can pick up items in the virtual environment and feel its weight and texture physically. Visitors can touch walls in the virtual environment and feel the tactility of touching a real wall. Haptic feedback vest also enables participants to physically feel impact experienced in the virtual world.

Figure 16-19: *The VOID gameplay*

Skin & Bones

In the Smithsonian National Museum of Natural History Bone Hall skeleton exhibition, visitors can use an augmented reality application to overlay skin and movement over skeletal to bring the animals back to life. Using headphones, visitors can also hear sounds from the animals' natural habitats during the AR experience. Those that cannot physically make it to the museum can download and use the application at home using images available on the museum's website for tracking and initiating the AR experience.

Figure 20: *Skin & Bones AR experience*

Retrace Raleigh

During my first semester at NC State, I collaborated with undergraduate students in a branding, service and interaction design course to develop a speculative design proposal for the Pope House Museum. The two-weeks design charrette was my first introduction to the Pope House and the significance of the Pope family to the City of Raleigh. My team developed the Retrace Raleigh mobile application to connect visitors to the contextual history surrounding the Pope House. As visitors leave the museum to explore downtown Raleigh, they unlock locations on a digital map found on the mobile application. Visitors can take photos of landmarks to compare to a historical image, allowing them to re-imagined what the areas surrounding Pope House looked like historically.

Retrace Raleigh was a significant inspiration for my thesis project. Besides being situated in the same context of the Pope House, the development of personas with unique motivation for visiting the museum, and using technology to give visitors a historical lens to view Raleigh's past, were sources of inspiration I drew from the project.

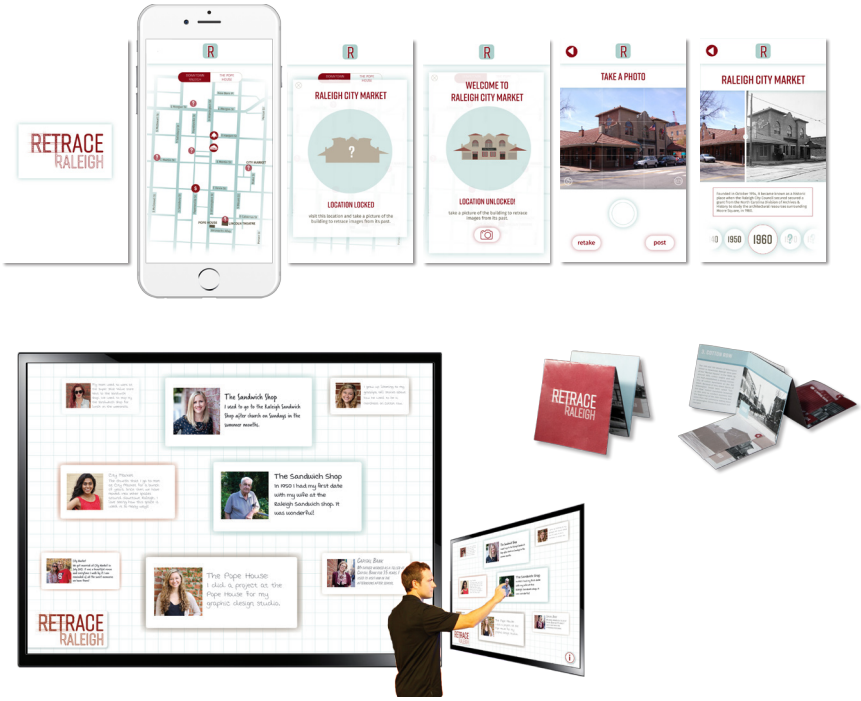


Figure 21: *Retrace Raleigh project deliverables*

I AM A MAN VR Experience

Developed by Derek Ham, the I AM A MAN VR Experience is set to the historical narrative of the 1968 Memphis Sanitation Workers Strike. In AM A MAN, participants walk in the steps of a sanitation worker in a series of immersive vignettes. "The vision is to give people an experience of history in a way that provides a more personal understanding of the struggles of these marginalized people," Dr. Ham states (Ham, nd). I AM A MAN's compelling story, centered around such an important moment in American history, played an intricate role in the success of the VR experience.

Figure 22: *I AM A MAN VR experience gameplay*

vMLK VR Experience

The vMLK VR Experience is a historical reenactment of Martin Luther King's "Fill Up the Jails" speech. King gave the historic speech just a few days after the Greensboro sit-ins in 1960. Using 3D spatial audio, participants can experience a unique perspective of the speech based on their location within the sanctuary. While the goal of the project was not to produce an identical reenactment of King's historic speech, it created a roadmap of how to develop a historical VR experience centered around sound.

Figure 23: *vMLK VR experience gameplay*

Anne Frank House VR

The VR experience transports participants into the Secret Annex of Anne Frank and the seven other people who hid with her during World War II. In the experience, participants can learn about Anne Frank's life within the annex in two different modes, Story Mode and Tour Mode. Story Mode last about 25 minutes. In Story Mode, Anne Frank guides participants through the rooms within the annex. Tour Mode provides participants the opportunity to freely explore the annex on their own. In both modes, participants can choose from seven different languages for the audio and text captions, making the experience accessible to a global audience.

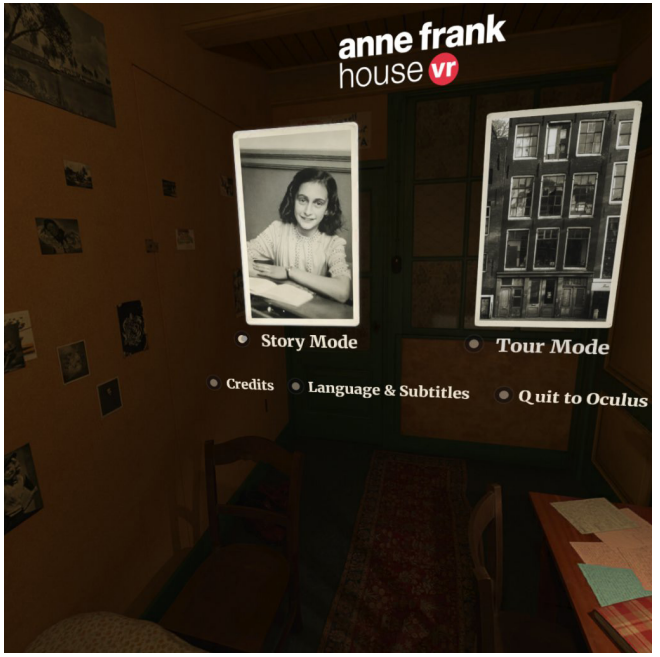


Figure 24: *Anne Frank House VR experience gameplay*

OBSERVATION STUDY

This is an overview of the observational study conducted at the Pope House Museum. As stated in the Research Methods section, I used a semi-structured observational approach. The visitors were aware of my presence both as an observer and participant in the tour. When the opportunity presented itself, I asked the visitors impromptu questions about their visit. Though not noted as a primary method of investigation, the responses gathered from visitors was vital to understanding how they felt about the tour, and considering ways through which mixed reality could help improve the house museum visitation experience.

Based on my observation, I realized that docents are integral to the visitation experience. They made the experience relatable to the visitors; Answering impromptu questions and drawing from their own experiences to keep visitors engaged during the tours. The conversation between the docents and visitors were also an essential part of the visitation tour.

During tours, I observed that visitors wanted to touch the artifacts, open doors to cabinets and entered rooms that they did not have access to. The lack of access to locked rooms and artifacts did not bring about any tension between curious visitors and docents but would have revealed more information about the home and increase satisfaction.

INTERVIEWS

During my interview with Ernest Dollar, director of the City of Raleigh Museum, he emphasized the challenges house museums are currently facing. "House museums are dying every day," Mr. Dollar declared as we discussed the dire state of historic homes. He stated that house museums are dying because of its immutable nature. "Once you see it, you go back 10 years later it's the same thing," he continued." But Mr. Dollar, like many museum managers, believes in the significance of house museums and continues to find new ways to contribute to the preservation of historic homes. As we concluded our discussion, he asked, "can we do the ultimate goal of the house museum— to make you believe these people just left. Can we, through technology, put the people back in the Pope House?"

A few days after my interview with Mr. Dollar, he scheduled a meeting with Edna Ballentine and I. Ms. Ballentine is a former caretaker of the Pope House. During our meeting, Edna spoke about her experience living with Ruth and Evelyn Pope, and their role in establishing the Pope House as a museum. As a child growing up in Raleigh, the Pope sisters took care of Edna. She recalls Evelyn fixing her hair in the morning as she prepared for school. After the Pope sisters moved away from home to pursue their respective careers, Edna was left as a caretaker of the home. When Ruth and Evelyn returned to Raleigh, Edna took care of them and in their family home until the two sisters passed away. During my conversation with Edna, she also spoke about specific renovations she made to the home after Ruth and Evelyn's death. The renovations were necessary due to flooding caused by a damaged water pipe in the home. Significant renovations she made after the flooding included replacing the tiles on the downstairs floor, and reconstructing the handrails on the staircase.

Ernest Dollar
Director, City of Raleigh Museum

House museums are dying every day

PERSONAS

Based on my observational study, I created the following personas and journey map to encapsulate the motivations and experiences of the broader range of visitors that would potentially come to the Pope House Museum. Pain points considered during the visitation tours informed the design interventions and features incorporated within the final prototype.

Henry Clark
Age: 47
Hometown: Philadelphia, PA
Occupation: History teacher

Henry is a native of Charlotte, NC where he currently lives and teaches History at a local high school. He enjoys taking his students on field trips to historic sites within their community. Henry visits Raleigh occasionally to attend teacher conferences and enjoys exploring the city historic districts. Henry owns a smartphone that he carries around with him to take photos and document places of interest to share with his students.

Motivation: Learning about the holistic history of the Pope House Museum

Natalie Henderson
Age: 24
Hometown: Charlotte, NC
Occupation: Grad student

Natalie is first-year graduate student at Shaw University. She's currently pursuing a master's degree in Cultural Anthropology with a concentration in 20th century African American culture and religion. Natalie recently found out about the Pope House Museum during a class discussion.

Motivation: Learning about the home life of the Pope family and how their experiences tell a broader narrative of African American home life and religion in Raleigh during the 20th century.

USER JOURNEY | HENRY'S VISIT

10:20 am

Context: Henry walks into the Pope House Museum and a docent greets him at the door. The docent asks Henry if he would like a tour of the home, and he says yes.

Pain Point: N/A

10:25 am

Context: As the tour commences, the docent tells Henry about the history of the Pope House and points to photos on the piano as she discussed the home life of the Pope family. When the docent points to a photo of Ruth, Dr. Pope's first daughter, Henry asks if she knew which year the photograph was taken. The docent acknowledges Henry but states she doesn't know the exact year the photo was taken.

Pain Point: Lack of historical information and inability to closely observe the photograph

10:30 am

Context: Docent resumes the conversation by the piano in the formal parlor and tells Henry about the story of Ruth Pope gnawing on the piano to get her mother's attention. Henry attempts to play the piano, but the docent reminds him that visitors could not touch artifacts in the house.

Pain Point: Cannot play the piano

10:40 am

Context: Now standing by the window in the formal parlor, the docent begins to tell Henry about African American life in the historic Pope House segregated neighborhood. Pointing to the north of the building, she mentions that black children, such as Ruth and Evelyn were not allowed to cross Wilmington street to play with the white kids. Looking outside through the window, Henry asks the docent if there are any historical photo of the kid playing in the neighborhood. Docent tells Henry that unfortunately, they do not have a historical photo of the neighborhood currently exhibited.

Pain Point: No historic photos showing the Pope House historic neighborhood

10:50 am

Context: As the tour continues, the docent tells Henry about Dr. Pope military career. Still fascinated about the story of children being unable to play together due to segregation, Henry starts to reflect on this own life ground up in a all white community and does not comprehend what the docent stated about Dr. Pope military life. Embarrassed to asked the docent to repeat herself, Henry pretends he understood what she was saying.

Pain Point: Cannot comprehend information while reflecting

11:00 am

Context: Now in the dining room, where artifacts are enclosed in a case, Henry becomes interested in Dr. Pope's revolver, but remembers that he cannot physically interact with it. So Henry loses interest and doesn't bother asking the docent about the revolver.

Pain Point: Cannot interact with artifacts enclosed in a display case.

11:30 am

Context: After the completion of the tour, Henry picks up a postcard to take with him to show his students.

Pain Point: N/A

DESIGN STUDIES

I conducted the following design studies without the conceptual matrix to experiment with different mediums and content that could inform the development of the AR experience prototype.

POPE HOUSE
WEB AR

As I started to narrow the focus of my final project, I created small studies to explore several ways in which I could materialize the research. During the preparatory stages of the investigation, I centered the research around design as a tool for cultural preservation. I asked, “how designers could use design methods and principles to aid communities with the preservation of material and immaterial cultural artifacts?” This inquiry led to the development of a web-based augmented reality project created using PlayCanvas. PlayCanvas is an open source 3D Web Graphics Library (WebGL) game engine that allows multiple developers to simultaneously work on a project. While I was still figuring out the content and context of the investigation, it was important to experimented with different platforms to gauge which would be best suited for developing the final prototype.

Process

I began by creating a 3D model of the Pope House exterior using Maya and Photoshop. I used Adobe Photoshop to extrude a 2D photo of the Pope House before bringing the model into Maya for refinement. Extrusion in Photoshop is a quick and straightforward process that was ideal for creating the models needed for the web-based augmented reality experimentation. However, due to formatting issues that occurs when exporting a 3D object from Photoshop for online use, the Pope House model was unusable

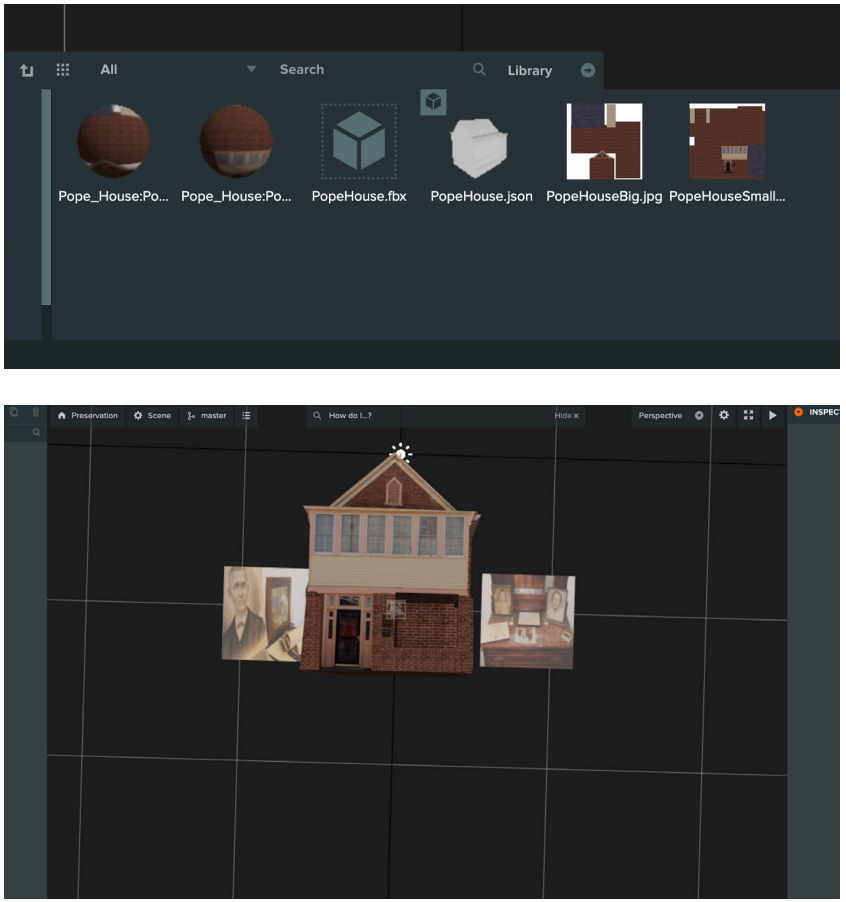


Figure 25-26: *Screenshot of PlayCanvas workarea*

within the PlayCanvas web editor. Importing the model into Maya, allowed me to quickly optimize it for web use. PlayCanvas also use a trackable marker to initiate the web-based augmented reality experience. While the platform provides a default Hiro web tracker for quick development and testing, having control over how the aesthetic of the tracker was essential to the study. Therefore, I created a customized tracker using the ARToolKit Marker Generator. I Imported the marker, 3D model, sound and images as assets into PlayCanvas to develop the web-based AR prototype. I regularly tested the prototype during the development process, making revisions as needed.

Reflection

I gathered the following insights after developing and testing the web-based AR prototype using PlayCanvas. A web-based AR experience is more accessible to museum visitors. Prompting visitors to download an application they may only use during a single visit may not be as resourceful. A link to an online experience, gives quicker access to visitors, in comparison to downloading an application. However, a limitation to web-based experiences is that it requires an internet connection. Losing connection during an augmented reality experience may decrease visitors' satisfaction during a tour.

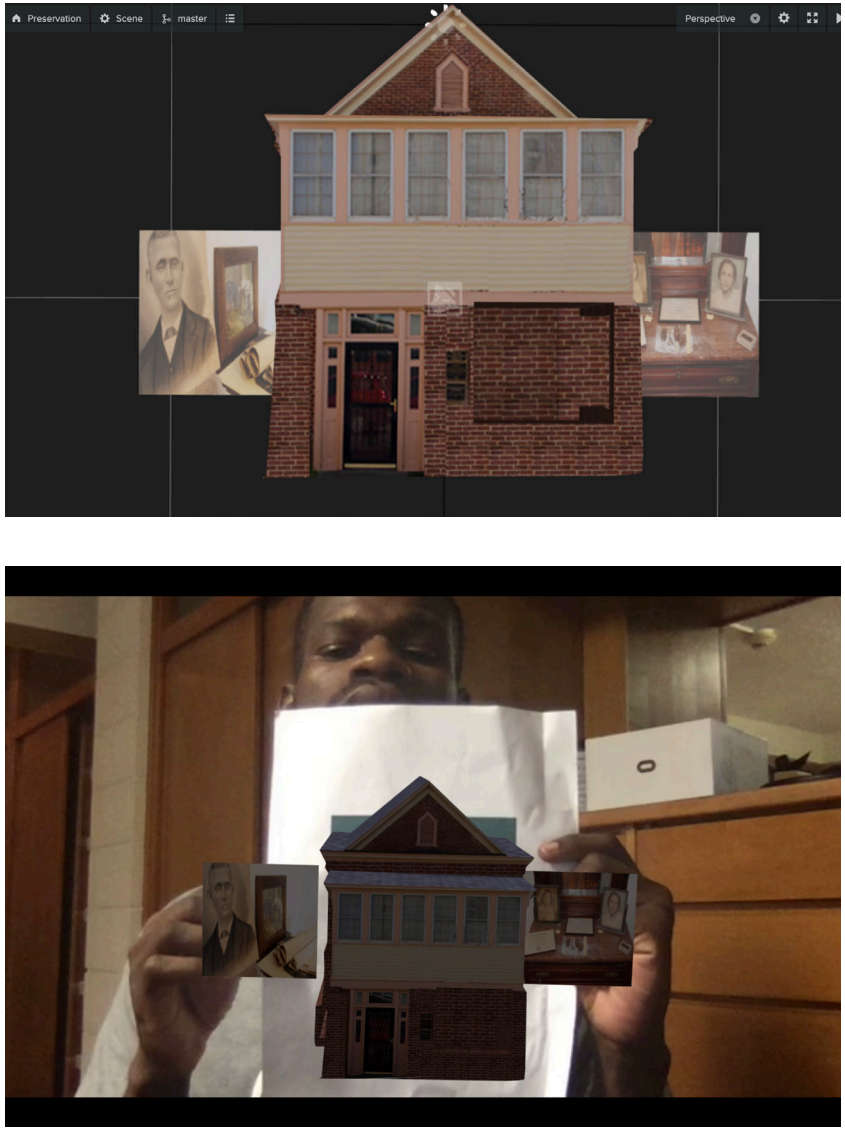


Figure 27-28: *Pope House WebAR prototype testing*

INTERPRETIVE ZONES: CATEGORIZING MEANING

This study considers how system design, specifically user interfaces in virtual reality, can help participants gain a holistic understanding of the characteristics of material artifacts exhibited within a house museum. Secondly, this study explored how the implementation of location-based virtual reality systems into house museums could increase visitors' participation during a visit. Location-based virtual reality is an immersive experience in which a digital environment blended over a physical place enables participants to navigate and interact with both real and digital worlds simultaneously. Virtual reality, especially those that are location-based, provides a new space within which multiple zones of understanding and interpretation of material artifacts can be experienced. How we visualized these zones within different historical context creates new opportunities for designers to explore the full potential of location-based virtual reality systems in house museums.

Process

To materialize this study, I came up with the concept of Interpretive Zone. Interpretive Zones is a design approach for grouping and visualizing multiple levels of information within location-based virtual reality experiences. I created a diagram depicting four essential functionalities of material artifacts (Figure 29). Informed by the diagram, I developed six different zones of understanding: Creation, History, Symbolism, Parts, and Usage. Finally, I applied the system to the visualization of a museum artifact, a house knife, to show an example of how to implement the zones of understanding (Figure 30).

Reflection

The goal of this study was to create a user interface system that helps visitors establish connections between related information about historic museum artifacts with little dependency on digital magic. I refer to digital magic in this context as user interactions that are only possible or dynamically enhanced in virtual environments—teleportation for example. At the completion of this study and upon further reflection, I concluded that when developing location-based immersive historic experiences, designers should aim to create UI elements that have similar aesthetics and interactions as the physical environment within which the visitor is present. For example, if the artifact or exhibition is archaic, the user interface should reflect a similar archaic aesthetic.

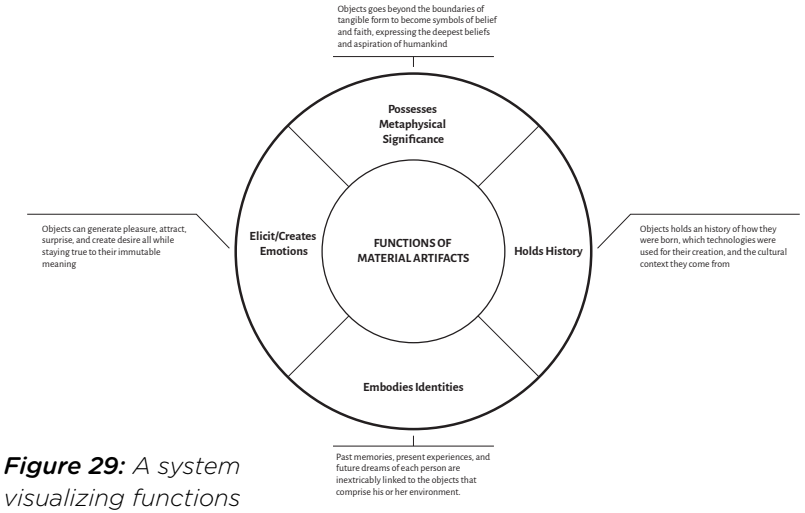


Figure 29: *A system visualizing functions of material artifacts*

Figure 30: *A visualization of a house knife zones of understanding*

Figure 31-32: *Oculus controller attached to a real chair and a virtual model*

TRACKING A CHAIR IN VR

For this final mini-study, I continued the exploration of location-based virtual reality systems. Specifically, I explored the feasibility of tracking a physical object in a virtual reality environment. In location-based immersive experiences, such as the VOID, developers have devised methods of tracking physical objects from the real world in real-time. Embedded transmitters and sensors makes it possible for the system to track the position and states of objects in the virtual environment.

Although available in retail stores, the HTC Vive tracker and other transmitters alike are a bit pricey. A single Vive tracker currently carries a price tag of $99. Unfortunately, I did not have the means of getting access to trackers used for bringing real items into virtual environments. After further research on an affordable approach to tracking physical items in VR, using the Oculus six-degrees of freedom (6DoF) motion controller, I developed a strategy to track a real chair in a virtual reality experience.

Process

I used a structure scanner to create a digital model of an office chair. I refined the model in Maya before bringing it into Unity Game Engine. The goal was to use the physical chair to track the digitally recreated model in virtual reality. Without access to an eternal tracker, I wrote a script that enable the Oculus controller to maneuver the position and rotation of the virtual chair. The script was successful when I could physically move the controller and simultaneously change the transformation of the virtual chair. The next step was to use the real chair to track its virtual replicate. To do this, I attached the controller to the real chair and meticulously place a digital replica of the controller in the same location on the virtual chair (Figure 31-32). Because the position and rotation of the physical and digital model of the controller were exact match, I was now able to use the real chair to control the transformation of its virtual replica.

Reflection

Using the Oculus controller to track a physical chair in an immersive experience was plausible. But this approach is limiting because of the lack of scalability. Having access to only two controllers, I could only track one object at a time. The challenges and limitations observed during this mini-study, broaden the focus of my investigation from location-based virtual reality system to mixed reality systems. While location-based virtual reality provides a higher level of immersion and virtual presence, implementing the system required a great deal of hardware and additional resources I did not have access to during this investigation. Limited access to the Pope House museum also proved to be a challenge. Being physically present in the space for which you are developing a virtual environment, is essential to the development and testing of a location-based VR experience. Though not as immersive, subsets of mixed reality experiences such as augmented and hybrid reality, are great alternatives to location-based VR. Thus, shifting my research focus to augmented and hybrid reality provided more opportunities to explore the implementation of mixed reality systems in house museums.

DEVELOPING PROTOTYPE

This section provides a brief overview of the software, hardware, tools, and resources used to develop the augmented reality experience prototype for the Pope House Museum.

PREPARATION

3D Scanning

I worked with Colin Keenan, an NC State library technician, to scan and create digital models of artifacts exhibited in the Pope House Museum (Figure 33). The 3D models serve as a digital archive of the museum's physical artifacts, and virtual assets used to develop the prototype. We used Artec Eva 3D scanner with structured light scanning technology to protect the historic artifacts from physical damages during the 3D scan.

Photo Documentation

One of the limitations I had during the development of the prototype was restricted access to the Pope House Museum. With access only on Saturdays and occasionally during the week, I took hundreds of photos that served as reference points as I developed the prototype. I also used some of the photos as markers for initiating and tracking the AR design elements. Using the photos as trackers enabled me to test the prototype in the design studio at times when I could not be physically present at the museum.

Audio Documentation

On Saturdays at the Pope House, when the docents were available, I spoke with them about their experiences leading tours and interacting with visitors. Information gathered from our conversations served as a foundation upon which I developed the augmented reality prototype. With their consent, I recorded audio clips of the docents as they led tours, and at times in a controlled setting. I used the recordings to create the audio tour features incorporated within the AR prototype.

3D Modeling

I recorded measurements of the rooms and took 360-degree images to use as references for creating a 3D model of the interior of the Pope House. An initial concept was to use the digital model to develop a location-based VR experience that would overlay the virtual museum over the physical environment. But as discussed in the early exploration section, the lack of resources proved to be a challenge when considering the development of a location-based VR experience for the Pope House Museum. However, the 3D model was useful in visualizing and rendering virtual scenes used in the augmented reality experience.

Figure 33: *Colin Keenan 3D scans museum artifacts at the Pope House*

PLATFORMS

Maya

Autodesk Maya is a 3D animation, modeling, simulation, and rendering software that runs on Windows, macOS and Linux operating systems. Maya parent company, Autodesk, updates the software once a year. Industry leading filmmakers and game developers use Maya to create digital environments, model virtual characters, and create digital animations for their respective projects. I became aware of Maya in a 3D production course during the final semester of my undergraduate studies. My proficiency with the software fueled my interest in other applications of 3D models, such as the development of virtual reality experiences.

For this investigation, I primarily used Maya to refine the scanned artifacts from the Pope House Museum, and to create additional 3D models used for the development of the AR experience. Of all assets created in Maya, the interior of the Pope House was the most challenging to design. I used exact measurements of the Pope House, so that the virtual model would be the same scale as the real museum. Creating an precise model of the digital environment so it matches the physical environment is essential to the creation of location-based mixed and virtual reality experiences, since participants move within both spaces simultaneously.

Unity

Unity is one of the industry leading cross-platform game development engines for creating 2D, 3D, and virtual reality experiences. The platform allows seamless integration with other development and design software, making the interface and usability of Unity extremely user-friendly. Released in 2008, updates of Unity are regularly made available to developers, addressing bug fixes from previous versions.

For this investigation, I used Unity to develop the AR experience prototype and design studies. While I was familiar with using the platform to create virtual reality experiences, this investigation was my first attempt of using Unity to develop an augmented reality application. I wrote the code of the experience using Visual Studio, an integrated development environment (IDE) created by Microsoft. Visual Studio seamlessly integrates with Unity and gives helpful suggestions when writing a script using the code editor. I programmed all the scripts for the prototype using the C# coding language.

Vuforia

Developed by PTC Inc., Vuforia is one of the leading technologies for developing industrial augmented reality experiences for handheld and digital see-through devices. Over 600K+ registered developers, across hundreds of enterprises, currently uses Vuforia. Vuforia uses computer vision for real time tracking of images, 3D objects and ground planes. Vuforia has its own standalone studio for creating

CONT...

AR and MR experiences, but it also has a software development kit (SDK) that easily integrates within Unity Game Engine. The SDK includes packages that contains example scenes and scripts to help developers get started on creating AR experiences with little coding knowledge. For this investigation, I used the Vuforia integration in Unity to create the augmented reality prototype. I wrote all the scripts and designed the scenes for the prototype from scratch, as I wanted to ensure I had control over the functionalities of the experiences and fix bugs in the code as needed.

Adobe Creative Cloud

Adobe Creative Cloud is a of applications used for editing visual and audio content. Creative Cloud applications are the go to software used by graphic designers, photographers, web developers, and filmmakers. Photoshop, Illustrator and Audition were the primary three Creative Cloud applications used during the development of the prototype. I used Photoshop to create the textures for the 3D models and Audition to edit the audio recordings. I designed the branded Vuforia AR markers, known as VuMark, in Illustrator.

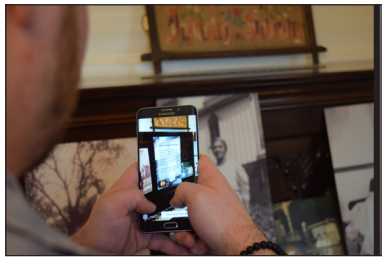
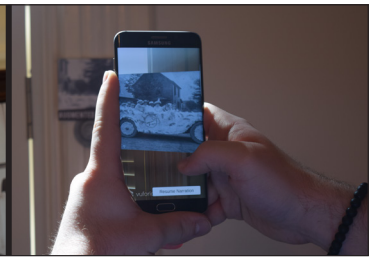
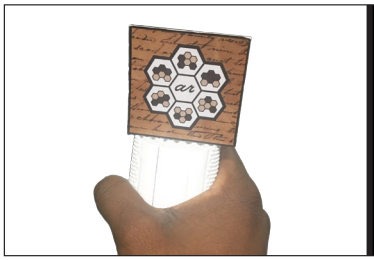
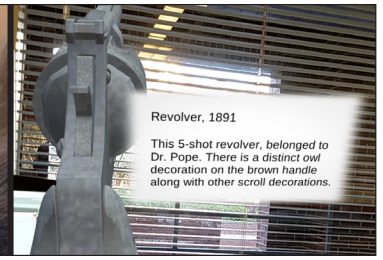
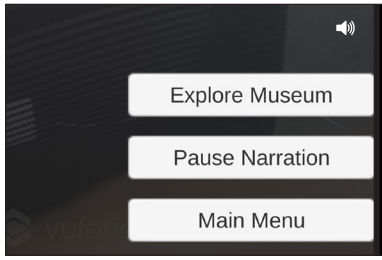
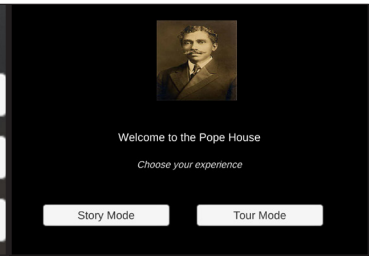
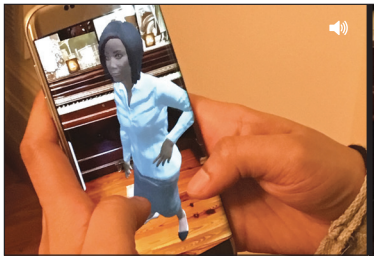
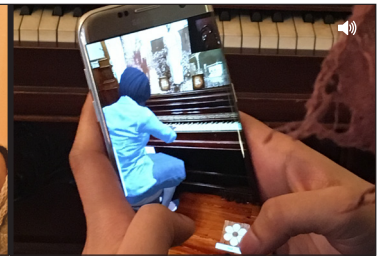
Android

Android is an operating system used by Samsung mobile devices. Unlike the iOS operating system, developed exclusively for Apple devices, Android is more accessible and has a seamless pipeline for developing and deploying AR experiences on all android-enabled smartphones. I built and tested the augmented reality prototype using two Samsung S7 Edge smartphones.

CONCEPTUAL MATRIX EXPLAINED

This section provides an overview of how I used the conceptual matrix to inform the development of the prototype. It contains a detailed analysis of how I incorporated elements of the Virtuality Continuum, Mobile Media Alignment framework, and Experiential Value taxonomy into the design and development of the prototype. While I considered how different cells with the matrix could informed features of the mixed reality experience, the prototype incorporates all features into one standalone mobile application. I developed the prototype with the goal of creating a self-guided experience that would allow visitors to explore the museum with little input from the docents. I limited the design of the prototype to the formal parlor and dining room of the Pope House, with consideration that the framework used to develop the MR application can be scaled to encompass the entirety of the museum experience. The formal parlor and dining room are key locations in the Pope House that contains prominent museum artifacts collected by the Pope family.

Table 2: Completed Conceptual Matrix

	Augmented Reality (AR)		Hybrid Reality (HR)	
Location Alignment				
Spatial Alignment				
Contextual Alignment				
	Playfulness	Aesthetic	Playfulness	Aesthetic

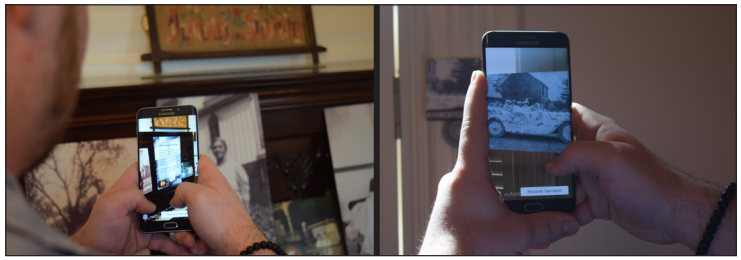
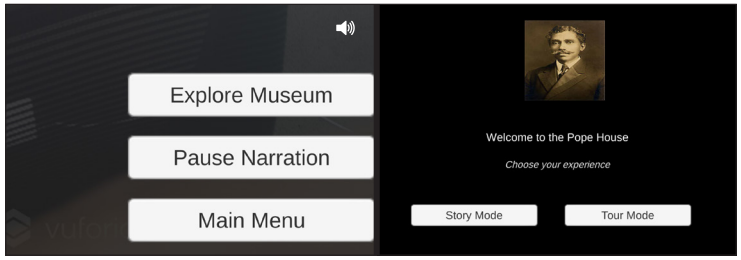
Augmented Reality

Location Alignment: Oppegaard refers to location as the conditions under which interaction occurs and the context from which we incorporate information into use (Oppegaard, 2017). It is through location alignment that both spatial and contextual alignment becomes a possibility (Oppegaard, 2017). For the augmented reality feature of the prototype, I regarded location alignment as the places within the museum that would benefit the most from the implantation of an augmented experience and the means through which the device would trigger AR experiences. For example, during the observational study, I realized that the piano in the former parlor was an important artifact and location during in the Pope House due to its significance to the family. Docents referred to pictures placed on the piano to describe the individual lives of the Pope family members. For the self-guided AR experience, I used the location surrounding the piano and photos as image markers to trigger augmented experiences that provided information to visitors using visual and verbal cues.

Spatial Alignment: Oppegaard describes Spatial Alignment as an awareness of everything physically nearby the user yet outside of their direct perceptions (Oppegaard, 2017). Contextual information visitors receive about renovations made to the home through their interaction with the family photos are examples of Spatial Alignment. Another artifact in the home used to explore spatial alignment is the large window in the formal parlor where docents provides visitors with information about African American life in historic Raleigh. Visitors gathered at the window and stare outside as the docent described what the exterior of the Pope House once looked like in the segregated neighborhood. To provide spatial information at this location, I used an AR marker to trigger an augmented scene. When visitors point their camera at the marker, they see a historical image of the exterior of the home within the window frames, providing a point of reference for what the Pope House neighborhood looked like historically.

Contextual Alignment: Oppegaard refers to Contextual Alignment as the precise matching of experiences to user's needs in the specific context of the user and in customized configurations (Oppegaard, 2017). A practical example of contextual alignment would ideally involve using machine learning technology to analyze a person's daily patterns and behavior to provide suggested activities to the individual. This exploration refers to contextual alignment as the act of providing agency to visitors to decide their own visitation experience. While the prototype does not utilized machine learning, data collected from the observation study served as the basis upon which I developed the various features visitors can choose from to customize their visitation experience. Contextual alignment features include the ability to visitor choose between two visitation modes. In Story Mode, a virtual docent guides the visitors through the museum though a linear progression. Tour Mode allows visitors to freely explore the museum, interacting with artifacts based on their interest, without an aided virtual or real docent.

Table 3: Completed Conceptual Matrix highlighting AR design studies

	Augmented Reality (AR)		Hybrid Reality (HR)	
Location Alignment				
Spatial Alignment				
Contextual Alignment				
	Playfulness	Aesthetic	Playfulness	Aesthetic

Hybrid Reality

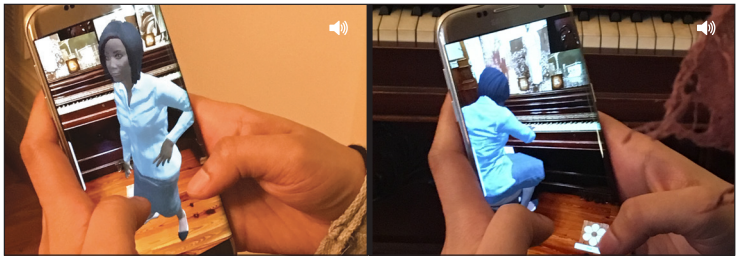
Location Alignment: According to Neal et al, handling artifacts provides spatial and physical understanding of the artifact (2013). Docents advise visitors to not touch exhibited artifacts during visitation tours at the Pope House. Therefore, when considering Location alignment for the hybrid reality experience, I used 3D printed objects to serve as triggers upon which I could render virtual models of the artifact. For this exploration, I 3D printed a handle of a revolver, enclosed in a display case, to give visitors the sensation of physically handling the artifact.

Spatial Alignment: Artifacts in the display case at Pope House were taken from various locations within the home and exhibited in the dining area. Spatial Alignment in this exploration, therefore involved providing visitors with contextual information about the original places in the home where curators collected the artifacts from.

Contextual Alignment: For the contextual alignment exploration, I considered hybrid reality as the interaction between virtual and physical artifacts within the house that immerses visitors in the historic home life of the Pope family. Using virtual avatars of the family, I considered how the system could give a distinct perspective of the home by allowing visitors to choose a family member to lead their tour. An example explored in the prototype used a virtual avatar of Dr. Pope's wife, Delia, to tell a story documented in her daughter's autobiography. According to her autobiography, Ruth once gnawed on the piano in the formal parlor to get her mother' attention. In the prototype experience, visitors can point their device at a marker next to the piano to trigger a virtual avatar of Delia playing the piano. As Delia plays the piano, visitors can prompt her to tell the story of Ruth gnawing the piano by pressing the "Tell Story" button on their device screen.

Playfulness/Aesthetics: All the features of the AR and HR experiences incorporate elements of both playfulness and aesthetic values. Mathewick et. al refers to play as an active engagement within an activity (Mathwick et. al, 2001). Aesthetics is as an appreciation of some consumption experience (Holbrook, 1999). Because both playfulness and aesthetic are self-oriented values (Holbrook, 1999), I designed the prototype to give visitors agency in choosing their visitation experience. The interactive elements of the interface create an opportunity for visitors to remain engaged in the visitation experience.

Table 4: Completed Conceptual Matrix highlighting HR design studies

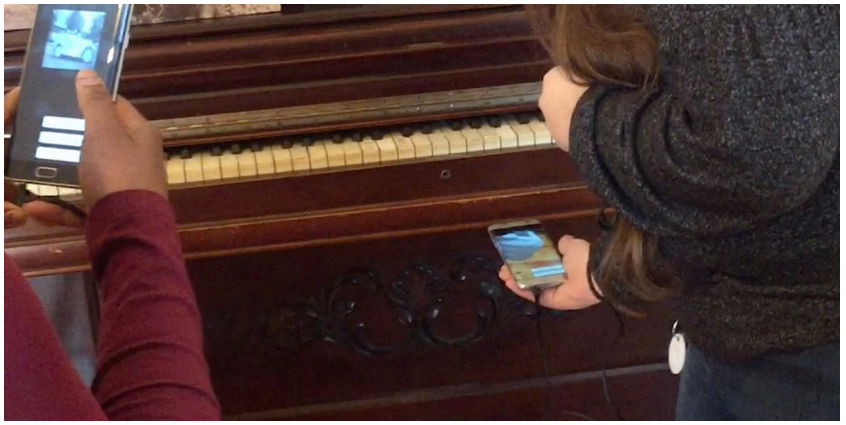
	Augmented Reality (AR)		Hybrid Reality (HR)	
	Playfulness	Aesthetic	Playfulness	Aesthetic
Location Alignment				
Spatial Alignment				
Contextual Alignment				

TESTING THE PROTOTYPE

Testing the mixed reality application at the Pope House was an essential part of the research investigation. Data collected from the visitors and docents during the user test provided insights on the usability of the AR trackers in different lighting conditions, and the user experience of the AR experience. To emulate the scenario articulated in the user journey map, participants began testing the prototype at the start of the tour and received instructions on how to use the application only upon request. With the participants' consent, I captured photos and videos as they interacted with the AR experience for documentation and further analysis.

Takeaways

The docents were excited about the potential of the prototype and how mixed reality can contribute to the preservation of the Pope House and the family legacy. Perhaps more rewarding was seeing the docents engage with application with little instructional guidance. Though it was only a prototype, the docents thought the system was ready for implementation. Feedback from the docents included suggestions on the placement of the AR markers within the home, re-recording the audio used in Story Mode to include a more descriptive narrative of the family lived experiences and material artifacts within the home. They also suggested that I change the names of the two visitation modes so that they are concise and descriptive of each experience.



Visitors seemed fascinated by the technology and often stated, "that's cool, or that's amazing," as they watched the virtual avatar play the piano. Most preferred Story Mode over Tour Mode, as the latter provided more context of the Pope family and followed a narrative. They also enjoyed physically holding the 3D printed handle and using it to maneuver the virtual model of Dr. Pope's revolver.

During user testing, I observed that photos used as markers were much easier to track and provided very little interruption. In contrast, the designed AR marker were much more difficult to track due to its size and low lighting within the museum. Markers placed on the floor provided more interruptions then those within arms reach of the visitors.

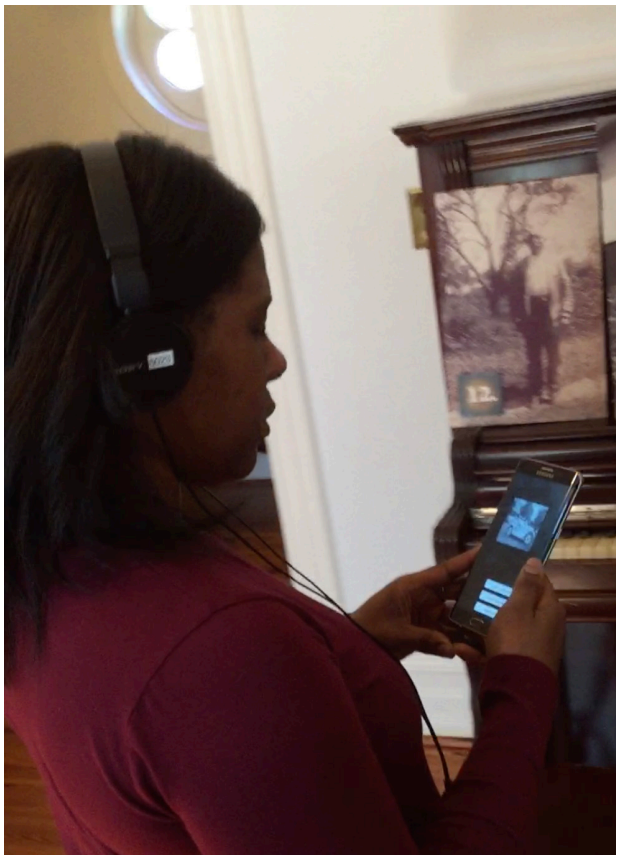


Figure 34-37: *Photos of participants testing the AR experience prototype*

REFLECTION & REFINEMENT

After reflecting on feedback gathered from user test, and analysis of the completed matrix, I refined the prototype to build on earlier concepts and introduce new ideas to push the design and features of the mixed reality system.

As I refined the prototype, I considered how the system could benefit from the implementation of time-based MR experiences. I asked, what if we could use MR to simulate a real-time presence of the family in the home based on occasions and time of day? Instead of presenting the family's lived experiences as a history that has already happened, this concept considers the presentation of historical narratives within the museum as living history. For example, based on their visitation preferences selected before or during tours, visitors can interact with a simulation of what the Pope family's home life would have been like at specific occasions and time of day. This concept also addresses the immutability concerns of house museums, as the MR simulation of the family's home life would constantly change to reflect different time periods.

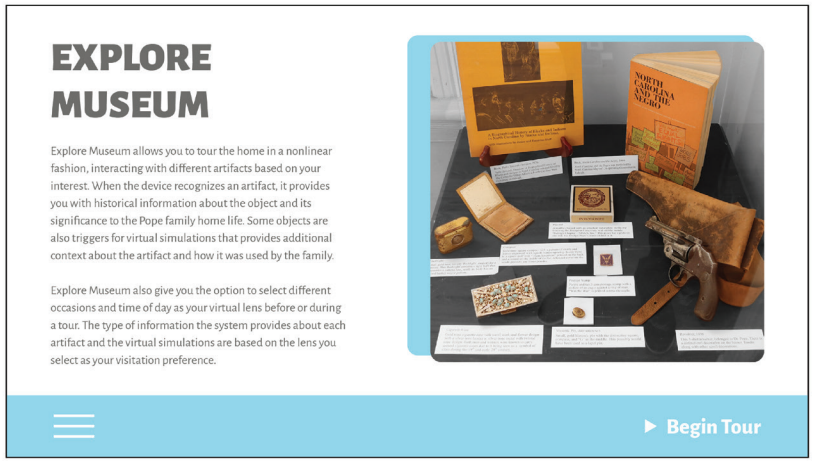


Figure 38: *Refined Pope House AR experience mobile interface*

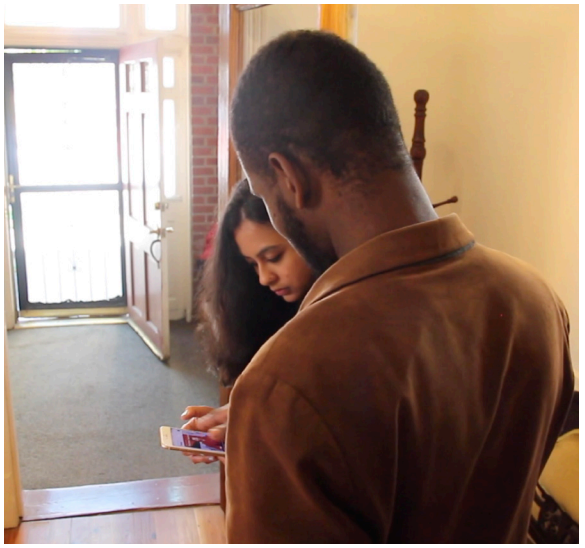
FINAL SCENARIO

In the following scenario, Natalie goes to the Pope House Museum after the implementation of the augmented reality experience to learn about the Pope family history and African American home life in the 2oth Century.

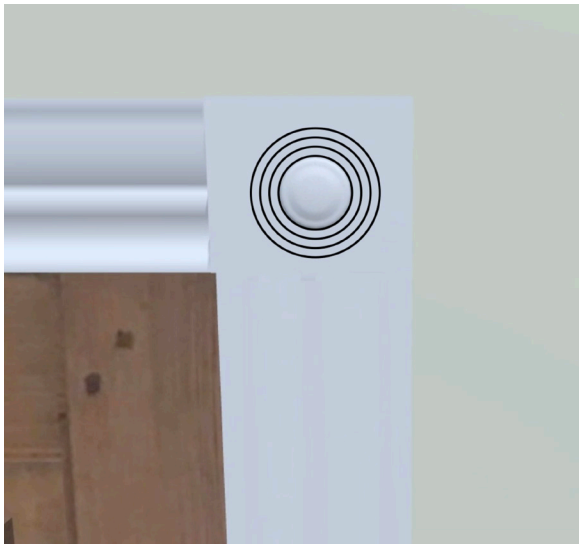
Natalie is a 24-year-old first-year graduate student at Shaw University. She's currently pursuing a master's degree in Cultural Anthropology with a concentration in 20th century African American culture and religion.

Natalie recently found out about the Pope House Museum during a class discussion. She Interested in learning about the Pope family history and African American home life in the 2oth Century, so Natalie visits the museum on to get a first-hand experience.

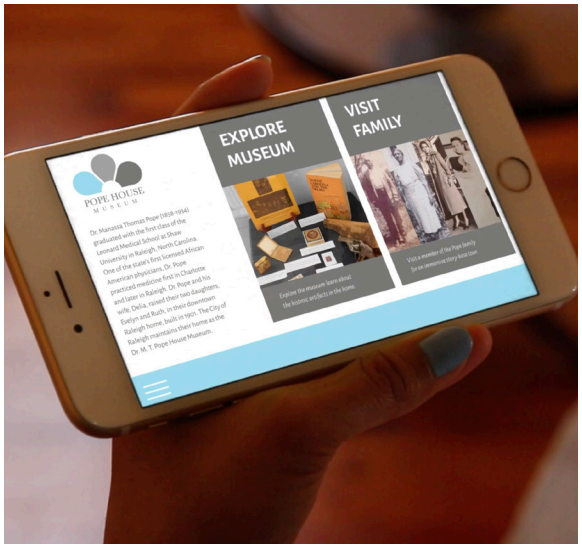
When Natalie arrives at the museum, she's greeted by a docent. The docent tells Natalie about the new Pope House augmented reality experience. Natalie agrees to try the experience.



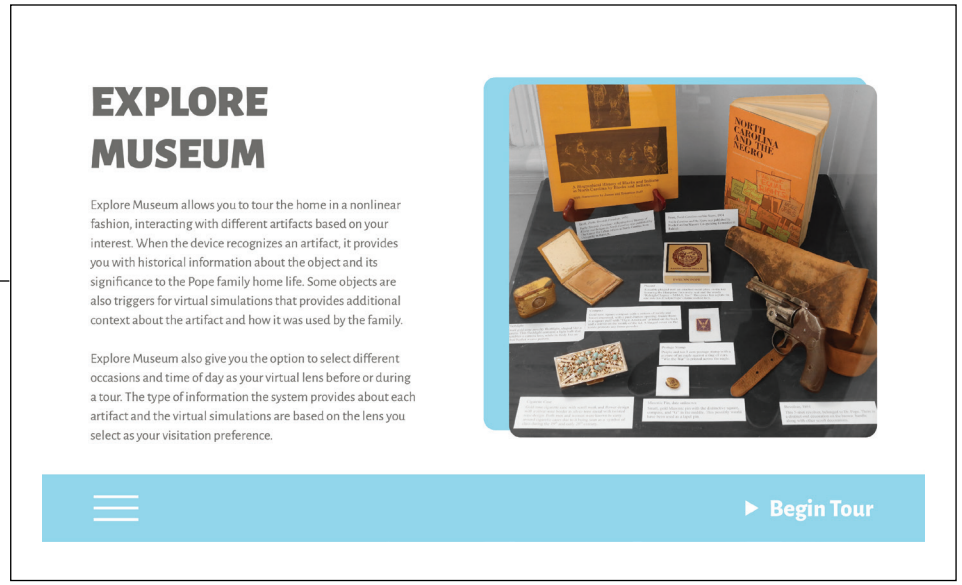
The docent assists Natalie with downloading the application to her smartphone and tells her that the tour is best experienced with headphones. Both the mobile device and headphones are also available to visitors upon request.



The system uses location-based iBeacon tracking to detect Natalie's position in the home and image recognition to identify artifacts using her smartphone's camera.



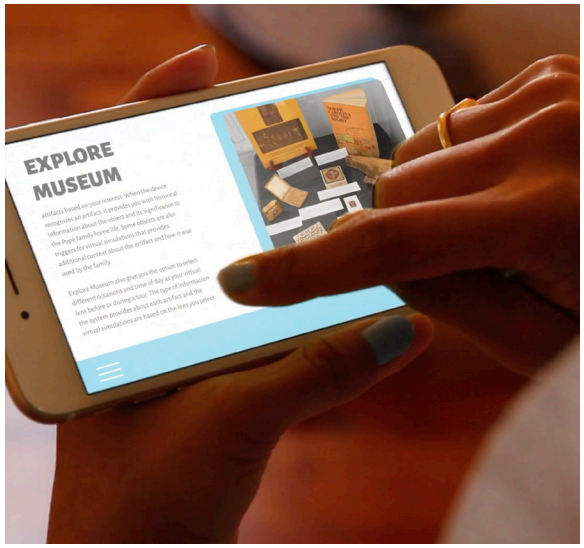
When Natalie first opens the augmented reality mobile application, she can choose from one of two visitation experiences.



Explore Museum allows Natalie to tour the home in a nonlinear fashion, interacting with different artifacts based on her interest. When the device recognizes an artifact, it provides Natalie historical information about the object and its significance to the Pope family home life. Some objects are also triggers for virtual simulations that provides additional context about the artifact and how it was used by the family.

Explore Museum also allows Natalie to select from different occasions and time of day as her virtual lens before or during a tour. The type of information the system provides to Natalie about each artifact and the virtual simulations are based on the lens she sets as her visitation preference.

The second visitation experience, Visit Family, gives Natalie the option to select a member of the Pope family to lead a story-based immersive tour of the home. Each story is told from the perspective of the family member that she chooses to visit with. Stories are based on national and local historical events of the 20th century that have a relevant connection to the Pope Family.



Wanting a holistic understanding of the Pope family home life, Natalie chooses to the Explore Museum visitation experience.

Natalie begins her tour in the formal parlor. The device recognizes her location and provides her with a description of the parlor:

"This formal parlor was primarily used when quest visited the Pope House. The sliding door which leads to the dining area was only open for special occasions."

The system prompts Natalie to point at the wall to see what the parlor historically looked like with wallpaper.

As she continues the tour, Natalie moves toward the piano in the parlor. When she points towards the piano, she receives a description stating:

"This piano was purchased by Dr. Pope for his first wife Lydia. It is an elegant mahogany upright piano made by the Crown Company of Chicago.

Recognizing that she's standing next to the piano, the system asked Natalie if she would like to see a simulation of Delia playing the piano. She confirms and a virtual avatar appears of Delia playing the piano.

Natalie continues her tour in the dining room. She positions her device camera over the dining table and sees a meal prepared by the family.

The meal shown on the table is based on the occasion and time of the day selected by Natalie.

Before concluding her visit, Natalie explored the rest of the Pope House learning about the family history and interacting with simulations suggested by the system based on her visitation preference and position within the museum.

DISCOVERY

CONCLUSIONS

This investigation explored how house museum can implement mixed reality systems to increase visitor's satisfaction. House museums are invaluable cultural resources that allow us to step back into a historic period and walk in the same space as those that once lived in the home. Unfortunately, at a time when other genres of museums are harnessing the power of immersive technology to attract visitors, house museums bear the responsibility of remaining immutable in a technology driven society. The goal of this project was to emphasize the cultural significance of house museums and contribute to its preservation using mixed reality experiences that complement the atmosphere within the home. It was important that the implementation of the system did not seem out of context but provided an additional lens through which visitors can experience the historical narratives present in the home.

Grounding the investigation in a real-world context at the Pope House Museum was an essential part of the design process. Gathering factual historical data about the Pope family that I used to develop the prototype allowed me to test the experiences in-situ and collect feedback from the museum stakeholders and visitors to improve the system's usability. Working with the museum staff and visitors to realize the vision of the project further emphasize the collaborative and interdisciplinary nature of the investigation. Designers and historians alike must continue to work together to find innovative ways to contribute to the preservation of house museums.

FUTURE POSSIBILITIES

This investigation opens the door to future possibilities for designers to explore and contribute to the historical preservation of house museums. Beyond augmented reality (AR) and hybrid reality (HR), designers can consider how the different experiences along the virtuality continuum can improve the house museum visitation experience. This investigation focused specifically on in-situ mixed reality (MR) experiences, but a virtual reality (VR) experience can provide access to house museums remotely. A complimentary VR experience can also address accessibility concerns. A VR experience provides an opportunity for those with mobility impairments to tour the museum from their own home.

While AR and HR provides a level of immersion, a location-based virtual reality experience would invoke a higher level of virtual presence. However, creating a virtual environment that overlays a physical museum environment would require full commitment from the museum officials. In addition to acquiring the needed resources, a successfully location-based virtual reality experience would require house museum officials to rearrange, archive, or replace original artifacts with 3D printed models that visitors can physically interact with.

Future investigations should also consider how MR and VR experiences developed to complement house museum visitation can facilitate interaction between museum visitors. Community involvement in the preservation of house museum provides new areas of opportunities for designers to consider when developing complementary immersive experiences. Therefore, designers must regard the house museum as a collective memory shaped by those that once lived in the house, and additionally community members and visitors that continue to contribute to the preservation of historic homes.

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APPENDIX


Millennial Dawn; Volume 1
The Divine Plan of the Ages
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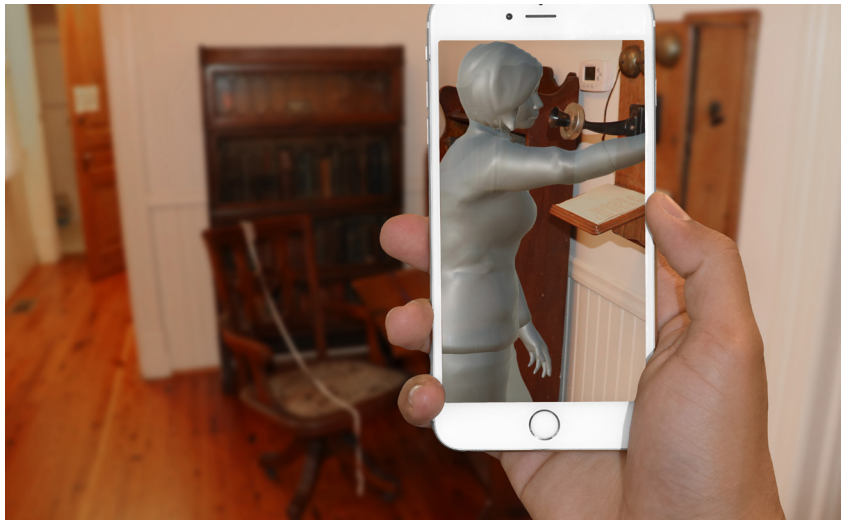

Additional design studies of
the Pope House AR experience