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REPRESENTING EARLY MODERN VENICE: AUGMENTED REALITY EXPERIENCES IN EXHIBITIONS[1]

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ABSTRACT | Two early modern prints that represent Venice—Jacopo de' Barbari's *View of Venice*, ca. 1500, and Ludovico Ughi's *Iconographica rappresentatione della inclita città di Venezia*, 1729— were the focal points of two interactive, multimedia exhibitions at Duke University in 2017 and 2019. The overall intention of these exhibitions was to enhance visitors' engagement with, and understanding of, the value of historic representations of places and spaces, while expanding cultural understandings of Venice, past and present. Placed in conversation with augmented reality (AR) technology, the novelty of the prints mirrored the methodological innovations of digital art history. The AR installations in each exhibition connected viewers with historic and present-day representations of Venice through virtual layers of information that encouraged them to return to the original objects for close engagement. This article describes the AR displays within the 2017 and 2019 exhibitions at Duke and presents the results of visitor interaction based on anonymous data and observation. It also documents AR installation strategies and methods, and it anticipates AR's applications and expansions for public-facing art historical scholarship. Finally, it shares these processes and findings in an effort to assist colleagues in the advancement of future installations at academic, museum, and cultural heritage institutions.

KEYWORDS | Augmented Reality, Early Modern Art, Exhibition/Presentation, Installation, Venice

Introduction

Two early modern prints that represent Venice—Jacopo de' Barbari's 1500 *View of Venice* (also known as *VENETIE MD*) and Ludovico Ughi's 1729 *Iconographica rappresentatione della inclita città di Venezia*—chronologically bracket the distinctive and influential typology of European cartographic visualizations (figs. 1 & 2).[2] The *View of Venice*, a bird's-eye view, was the mode of representing the city until Giuseppe Baroni printed Ughi's largely accurate topographical map more than two centuries later. Each of these multi-sheet, printed multiples formed the centerpiece for separate interactive, multimedia exhibitions at Duke University. In 2017, the exhibition *A Portrait of Venice* at the Nasher Museum of Art established a new exhibition model: one original work of art, de' Barbari's multi-sheet, large-scale print, was the point of departure for seven digital displays presenting stories about the *View* and sixteenth-century Venice, including an interactive augmented reality (AR). The second installation in 2019, *Senses of Venice*, emerged from the prototype established by the first. Exhibited in a highly visible, public space at Duke Libraries, it featured three digital displays that highlighted Ughi's album-bound map, alongside other precious books printed in Venice and presently housed in Duke's David M. Rubenstein Rare Book & Manuscript Library.[3] *Senses of Venice* focused on the eighteenth century, the Grand Tour, sensory experiences, and movement within the city. While independently conceived, the exhibitions were complementary in nature, much like the two cartographic representations that chronologically bracket the establishment of new modes of visualizing Venice. Designed to engage a wide and varied public, the exhibitions spotlighted the prints' visual novelty via digital storytelling. The complementary interactive displays within each exhibition served as vehicles for innovative content that followed digital art historical methodologies.[4] Guided by research questions, the digital functioned both as a tool and method to help the curator and content developers communicate research findings. An AR display in each exhibition offered a unique experience that supported the overarching thematics related to the original prints (woodcut and engraving). Specifically, the AR, as with the other displays, encouraged viewers to return to and investigate with close, slow, and measured looking, the original prints displayed within the same space.

Figure 1. Jacopo de' Barbari and Anton Kolb; A View of Venice; c. 1497-1500; Public Domain; https://idn.duke.edu/ark:/87924/r4k06zz0r.

Figure 2. Ludovico Ughi and Lodovico Furlanetto; Iconographica rappresentatione della inclita città di Venezia; 1739; Public Domain; This figure was digitally stitched together by Daphne Turan based on the version available in Duke Libraries' digital repository: https://repository.duke.edu/dc/maps/ughst001001

As monumental, iconic representations of the city, the two multi-sheet prints' complexity as artistic and technological achievements offered ideal points of departure for constructing historical narratives about early modern Venice within innovative exhibition contexts. The visualizations of these two images—a bird's-eye view and a mathematically formulated map (and hence mostly geo-rectifiable in GIS platforms)—reveal the scientific engagement of artists working in Venice. The representations are valuable not only as documents of cartographic impulses alive in Europe at the time of their making, but also for the rich detail that reflects the international interests of a cosmopolitan city-state. The printed format ensured transmissible information and, at times, propaganda for Venice in a reproducible and relatively cost-effective way. AR offers a commensurate, contemporary vehicle for promoting the value of these cultural objects, avant-garde for their time. The novelty of the prints, therefore, held great potential to mirror the methodological innovations in digital art history and advancements in AR technologies.

The overall intention of each exhibition was to enhance visitors' engagement with, and understanding of, the value of historic materials and cultural artifacts, as well as to expand their understanding of Venice from the past to the present. In addition to describing and considering the use of AR within the 2017 and 2019 exhibitions, this article assesses the outcomes of each AR experiment via quantitative and anecdotal evidence. The aggregated analysis of visitor interactions demonstrates how content presented through AR offers opportunities to mediate and enhance cultural heritage experiences. A further purpose of this paper is to share findings that assist in the development of future installations at academic, museum, and cultural heritage institutions. Finally, the developers/authors document installation strategies and methods for the use of AR in interactive exhibitions that anticipate applications and expansions for public-facing art historical scholarship as AR has become an increasingly accessible medium for reaching a diverse public with far-ranging backgrounds.[5] These findings target, in particular, those interested in the application and advancement of scholarly understandings for historically driven AR, the formation of forward-thinking installations, and the need to foreground the cultural artifacts within them.

Augmented Reality: Origins & Cultural Heritage Applications

While AR may appear relatively new to many audiences, the concept dates back to at least the 1960s with Ivan Sutherland's "Ultimate Display:" "a room within which the computer can control the existence of matter."[6] Sutherland sought to break barriers between physical and virtual realities. He combined virtual experiences humans could see and hear via a computer with experiences in the physical world to create a new, augmented reality. While virtual reality within CAVE-type display systems[7] has been achieved since,[8] many of today's AR technologies rely on screens or wearable devices to add virtual layers over or in front of physical spaces, as opposed to specific enclosed environments.[9] Creators can use these layers to establish relationships between physical and virtual objects and, in turn, develop these relationships to build narratives that generate meaning.

Broadly speaking, AR technologies use either location- or image-based information to connect digital content with points in space or specific objects. In location-based AR, a mobile device must be at or near a specific geographic coordinate in order to reveal digital content.[10] Alternatively, image-based AR requires visitors[11] to "scan" an image or barcode-type symbol such as a QR code[12] using the camera of a mobile device.[13] Given the object-oriented nature of many museums and libraries, image-based AR works well to generate interactive digital narratives around specific items in a collection or exhibition.[14]

Curators, scholars, designers, and developers have used a variety of technologies, including AR, to share narratives in ways that enrich audiences' cultural understandings. These interventions—sometimes playful, sometimes critical, and usually participatory—can engage visitors' imaginations as they explore historic spaces.[15] An early use of such technology is the audio tour, now standard practice in many cultural heritage settings. In the same decade that Sutherland dreamed of his ultimate display, the Science Museum in London experimented with radio-guided tours to augment visitors' experiences. The Science Museum developed what would later become known as an "exhibition landscape" in which the visual and aural were combined.[16] Instead of gazing at objects organized taxonomically, visitors to the Science Museum now experienced objects placed within a narrative based on each object's meaning and connections to other objects. The audio tour, a cousin to text informative didactic panels, labels, and interactive screens, persists today and has, in some cases, become entwined with other forms of exhibition augmentation.

Because of their compatibility with mobile devices, QR codes offer one access point to audio guides both inside and outside museums. In 2014, for example, Sing London launched *Talking Statues London*, a project that connects passersby with statues' stories narrated by actors and comedians.[17] To hear these stories, visitors could use their device's camera to scan the QR code located on or near a statue's blue plaque, a marker that signifies a historic site in London. These experiences connected tourists, commuters, and other curious visitors not only with the statue, but also with the person or event that the statue represents. Of course, sound is not the only type of media that can be shared via QR codes. Through the web, QR codes have the ability to connect users with text, video, images, 3D models, and more.[18]

Working with QR codes along with proprietary and open-source AR tools, cultural heritage institutions have developed mobile applications for visitors that offer exploratory experiences for them to find, view, listen to, and/or interact with digital content. Launched in 2015, the Smithsonian's *Skin and Bones* shares digital animations of specimens housed in the museum's Bone Hall.[19] Visitors point their mobile device's camera at a skeleton to reveal a 3D animation that, on the device's screen, appears to be moving in the hall. They can also choose to view supplementary content such as videos about the skeletons.

Meanwhile, other organizations have used AR beyond the museum's walls to engage their audiences directly with past and present visualizations of a space. The creators of the *Chicago 00 Project*, for example, developed applications that enabled visitors to explore the history of Chicago through the layering of historic photographs over the city's present-day environs.[20] Similarly, *GHETT/APP: Jewish Venice* presents the history of the Venetian Ghetto through the layering of 3D models, audio, and other media over present day Venice to help viewers engage with the site's critical history.[21] These projects ask their viewers to engage with the ways in which a city has and has not changed over time and to consider how others experienced the same urban spaces within earlier historical moments. These were embedded questions sought by the curator and developers for the AR in Duke's exhibitions.

The growing presence of AR in cultural heritage spaces indicates that many curators and scholars now see the ways that AR technologies can make an impact on and inform visitor experiences.[22] Indeed, these experiences have shifted beyond individual installations and can be found interwoven across entire museum landscapes. The National Museum of African American History & Culture, for example, offers a mobile application for its visitors. On site or at home, this application provides alternative ways of navigating the museum through both audio tour-style narratives and visual AR experiences.[23]

AR and other digital technologies are likewise intertwined with the history of teaching and research concerning Venice. Between 2002 and 2005, David Rosand, a former professor emeritus of art history at Columbia University, worked with the university's Media Center for Art History to develop a web-based teaching tool that enabled students to compare the architectural past and present of Venice. To do this, a digital magnifying glass enabled them to see "through" de' Barbari's *View* to aerial views and other visual media beneath.[24] A version of this work was also made available for Google Earth and included clickable images and panoramas layered over a satellite image of the city. Following a common web-based digital humanities format, another project, *The Grand Tour of Venice*, provides viewers with text, historic imagery, and audio narration to learn about Venice.[25] Deborah Howard and Laura Moretti's monograph *Sound and Space in Renaissance Venice: Architecture, Music, Acoustics* (2009) features an online accompanying project built in Adobe Flash that uses building plans and audio files to immerse readers/viewers/listeners aurally in a church's acoustics.[26] While these and other projects have offered important interventions at the intersection of digital art history and the study of Venetian culture, by contrast the curator of the Duke exhibitions and developers of the AR sought to create experiences that required physical presence in the exhibition spaces. Specifically, the AR was intended to facilitate social interactions and place technologically mediated installations in direct conversation with the works of art.

Such direct visual and virtual annotations of objects and monuments, however, have caused concern in the cultural heritage world. In 2016, *Art in America* editors Brian Droitcour and William S. Smith asked: "when the museum and its corporate partners bring these works 'to life' with cutting-edge tech, are they also implicitly declaring the death of the static art objects that fill physical galleries?"[27] Certainly, this question bears consideration: will AR generate demand for flashy virtual simulations of cultural heritage rather than for the cultural heritage itself, distancing viewers from the physical objects? Or, instead, will AR bring viewers closer to cultural heritage and prompt curiosity more aligned with the visions of Sutherland and the Science Museum's curators, among others? The authors of this paper take the latter, more optimistic approach and further these questions by asking: when and how can AR effectively bring past and present together in illuminating ways that facilitate closer engagement with an object or place? What can interactive, digital media platforms, which enable viewers to rotate, zoom, pan, swipe, and otherwise choose how they engage with content, contribute to museum goers' experiences? How does AR in museums create opportunities for social interactions that further enrich visitors' cultural experiences? Answers to these questions hold the potential to bring the practice of art history to the public at large.

AR Installations in *A Portrait of Venice* (2017) and *Senses of Venice* (2019)

Cultural heritage AR experiences collectively share at least one common feature: their historical narratives are fragmented. They bring the past into the present while ensuring viewers' awareness of the inevitable incompleteness, the loss of history, and/or its full sequencing.[28] By contrast, the AR installations described in this essay attempted the opposite: the authors augmented historical depictions of space with present-day representations. Instead of viewing history layered over the present, visitors to *A Portrait of Venice* (2017) and *Senses of Venice* (2019) viewed the present

layered over the past.[29] The intention was to engage visitors with the original works of art on display.

This focus on strengthening connections between museum visitors and the objects they view follows Jennifer Rich's 2016 argument that the introduction of audio tours in exhibitions recenters meaning-making on visitors' experiences of cultural objects.[30] AR and the virtual annotations used in *A Portrait of Venice* (2017) and *Senses of Venice* (2019) similarly emphasized relationships between visitors and objects. In both instances, viewers looked not through glass but through a tablet to see past and present representations of Venice brought together. For visitors familiar with the city, such viewing held the potential to spark a moment of recognition, connecting their memories with the sites depicted in historic images. For visitors unfamiliar with Venice, the contemporary imagery, videos, and 3D models brought historic spaces into the present. In both scenarios, AR experiences held the potential to strengthen visitors' connections between historic places and objects and between present-day and historic "viewers" of Venice. The ability for visitors to choose locations of interest and then to "discover" the interactive content within these sites permitted them to follow their interests and form connections to the city with minimal curatorial input. Furthermore, the ability to share the AR experience with fellow visitors offered occasions to see Venice and the *View* or Ughi map from others' perspectives as they watched other visitors navigate the AR, perhaps co-navigated together, or discussed the AR installation, its content, and/or what they were learning about Venice.

Each installation relied on image-based AR. Visitors used a tablet to scan a site depicted on the *View* or the Ughi map and then access content about their selected site. For *A Portrait of Venice* in 2017, the developers/authors understood that AR would not be possible with the original object because of the low lighting and glass protecting the first-state print, not to mention the distance required between visitors and the work on display. Instead, using a high-resolution digital image of the *View*,[31] the developers/authors designed a version scaled to approximately three quarters of the size of the original and had it printed on vinyl.[32] Creating this version enabled the annotation of each selected site on the *View*. For the installation, the curator decided to mount the vinyl version of the *View* on a wall directly across from the original first-state print to facilitate connections with the original object and to optimize viewing and looking.

Beneath the vinyl, two mounted Apple iPads enabled visitors to interact with the AR application. A wall-mounted stand cradled each tablet when not in use, tethered with their power and security cables to the wall. The tethers were long enough that visitors could scan the highest annotations (figs. 3 & 4).[33] Both tablets were locked into the installation's AR application, Zappar, using Apple's gallery mode.[34] The application's default state was to wait with the device's camera activated until a "zapcode," Zappar's proprietary marker similar to a QR code, appeared in the camera's view. A label to the right of the vinyl described the AR installation and how to interact with it, although the developers/authors occasionally observed that visitors moved directly to the mounted tablets where they could learn how to interact with the installation by observing another visitor, receive guidance from a passing museum staff member, or pick up the tablet and intuitively hold it so that the camera displayed a part of the vinyl on the tablet's screen.

Sites annotated with virtual content were marked on the vinyl using a white rectangular outline and a zapcode on one corner (fig. 5). When a visitor successfully scanned a site, a button labeled with the site name appeared on the screen. The visitor could tap the button to reveal content about the site (fig. 6). Content types included image sliders showing the present-day and/or past site, videos showing a particular aspect of a location, time lapse footage showing movement in and around the sites, and zoomable panoramas of city views. When visitors were finished with one site visit, they could tap the eye icon in the Zappar application to scan another site.[35]

Based on observation and evaluation of informal visitor feedback, the curator and developers found that the 2017 exhibition's uses of vinyl and tablets with AR technologies proved successful. With an eye toward furthering the initial concept, the developers/authors implemented a similar experience for the Ughi map in the 2019 *Senses of Venice* exhibition (figs. 7 & 8). The Ughi map, close to geo-rectifiable in contemporary GIS platforms, pointing to its overall scientific accuracy, and the imagery used for the AR (still photography, 360 degree views, and 3D models), illustrated how relatively accurate the viewpoints and mapping tools used in the eighteenth century were. The function of the present day photography alongside the Ughi imagery was, therefore, to demonstrate the scientific, cartographic, and representational methods employed to map eighteenth-century Venice alongside current digital methods, which were both advancements for their time. Unlike de' Barbari's *View*, assembled from six sheets to form a composite whole, the Ughi map held in Duke University Libraries is preserved in its original sheet format, with the separated sheets bound in a volume.[36] Following the perforated lines intended to indicate where the sheets would be cut and then reassembled, the original was digitally stitched together from high-resolution scans to form the complete, composite image.[37] A printed vinyl version of the image and accompanying label were mounted on a wall directly across from a central display case featuring the original volume. Open to a selected page, visitors could again—and at closer range this time—compare the original printed, bound section with the digitally assembled reproduction.

For the 2019 AR installation, the developers opted to build a custom AR application in Unity, a game development

Figure 3. Hannah L. Jacobs; The AR installation in A Portrait of Venice; 2017; The vinyl View mounted on a green wall with two iPads mounted underneath, ready for visitor interaction.

Figure 4. Hannah L. Jacobs; Museum visitors interacting with the AR installation in A Portrait of Venice; 2017; One person holds an iPad up to the vinyl View to capture a zapcode with the iPad camera and reveal AR content.

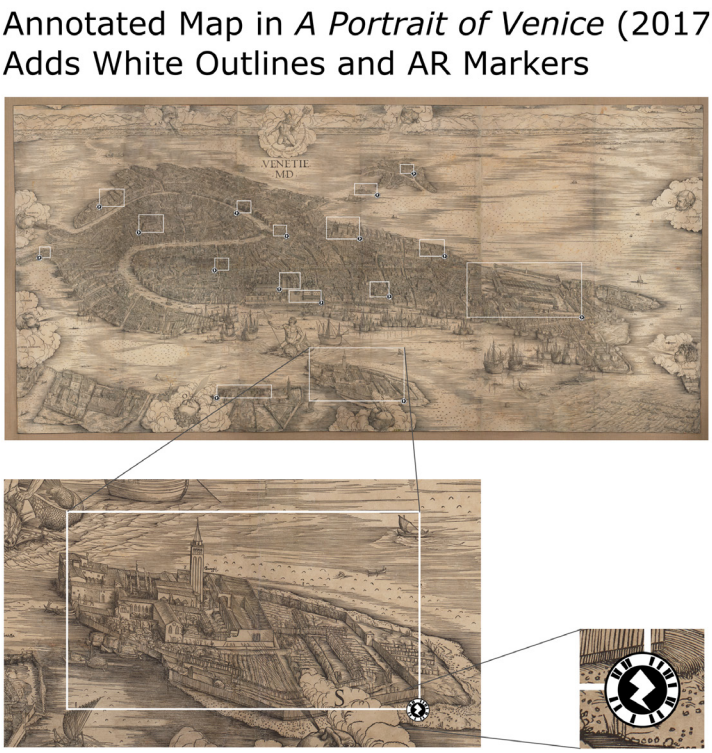

Figure 5. Hannah L. Jacobs; Annotated Map in A Portrait of Venice (2017) Adds White Outlines and AR Markers; 2021; Diagram showing the annotated View and the white boxes outlining each site with accompanying zapcode.

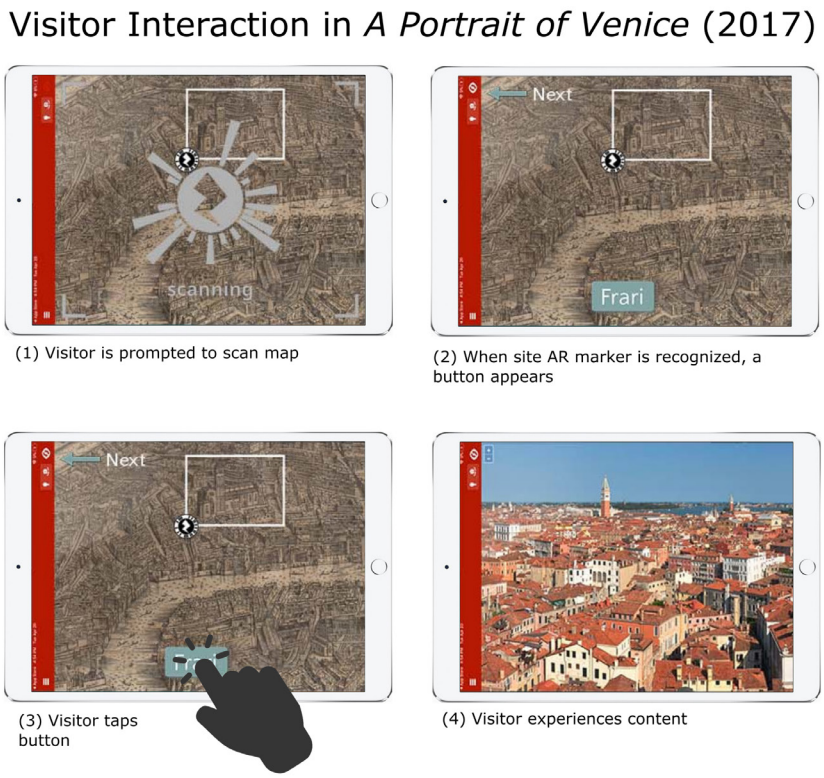

Figure 6. Hannah L. Jacobs; Visitor Interaction in A Portrait of Venice (2017); 2021; A grid of four iPads showing each step in the AR interaction: (1) Visitor is prompted to scan map; (2) When site AR marker is recognized, a button appears; (3) Visitor taps button; (4) Visitor experiences content.

Figure 7. Alina Taalman; The AR installation in Senses of Venice; 2019; photograph taken for the use of the project; the vinyl Ughi map hung on a red wall with an iPad stationed next to it, ready for visitor interaction.

Figure 8. Alina Taalman; An exhibition visitor interacts with the Senses of Venice AR installation; 2019; photograph taken for the use of the project; A visitor holds the iPad in front of herself and views a 360° image of Piazza San Marco.

software that enables custom design using either free or paid tools.[38] The custom application offered opportunities to build an interface specific to the exhibition's overarching narrative related to sensing or experiencing Venice, to manage analytics to a greater degree, and to take advantage of Unity's AR Foundation Library framework.[39] This framework required only unique images as markers to prompt interactions. The vignettes along the left and right sides of the image functioned as intrinsic interactive indicators. The vinyl Ughi map, therefore, required no additional annotation markers.

Given that the physical space for the 2019 installation was limited—both in terms of wall space and in terms of walking space between the wall and central display cases—only one tablet was installed to the left of the vinyl. This tablet was locked into the custom AR application built in Unity. Instructions for use were printed next to the display to provide visitors who had less technological familiarity with additional guidance. Picking up the tablet, a visitor was prompted by the application to scan one of the vignettes arranged along the sides of the map (fig. 11). When the application scanned and captured a vignette, it generated thin gray outlines around the vignette within the camera's line of vision. When visitors selected this vignette, the outline thickened and prompt buttons appeared at the bottom right of the screen. These buttons connected visitors to select content for viewing and interaction. In many instances, multiple types of content were available for a single site, a feature that evolved from the singular experience of the AR in *A Portrait of Venice*. Therefore, in the 2019 experience, visitors were able to view a 360-degree image, a 3D model, or a comparative image slider for a specific annotated site (figs. 8-10).[40]

An Analysis of the AR Installations & Visitor Interaction Data

The two AR installations were set in different exhibition contexts on Duke's campus. In 2017, *A Portrait of Venice* was presented across two interconnected rooms in the Nasher Museum of Art's main entry and exit of the pavilion dedicated to its permanent collection, as well as the adjacent incubator space for temporary installations. Visitors to the Nasher likely arrived with the primary aim of viewing and learning from cultural heritage objects.[41] They may have entered this part of the museum with one of two specific goals: to view some or all of the permanent collection or to view *A Portrait of Venice*. The AR installation was ideally placed along the path that visitors would take to meet one or both of these goals. Visitors might stop to interact with the installation on their way in or out of the permanent collection, or at the beginning and/or end of their visit to *A Portrait of Venice*. Occasionally, museum staff also interacted or helped visitors explore the AR content.[42]

The 2019 *Senses of Venice* exhibition was installed in the Jerry and Bruce Chappell Family Gallery, an interior transitional space between the entrance into the Duke University Library building on West Campus and the Perkins Library housed inside. This dedicated gallery, in addition to its function as a temporary exhibition space, acts as a passageway that many Duke community members and visitors move through on a daily, or even hourly basis as they enter and exit the library and a café situated between the gallery and the library's entrance. Visitors may have had widely diverging goals: to visit the exhibition may have been one primary goal, but other primary goals may have been to take a break during library use or a study session, to meet a colleague for lunch, or to participate in a campus tour that included learning about library resources. In these latter instances, visiting the *Senses of Venice* exhibition would have served a secondary goal—to engage, perhaps spontaneously, with a topic of interest while on the way toward meeting a primary goal. Additionally, because of the AR installation's placement in the gallery, visitors were most likely to see it, and therefore to engage with it, while intentionally moving around the gallery space to view the exhibition or seeing it while exiting the café or library.

The differences in potential visitor goals and the placement of each AR installation in the gallery space may have proven crucial factors in the level of visitor engagement.[43] Over the course of the exhibition, the 2017 AR installation had 8,216 total "site visits," or interactions with annotated locations on the *View*. Meanwhile, the 2019 installation received only 1,918 total site visits.[44] In 2017, even if visitors had not specifically intended to visit *A Portrait of Venice*, they had intended to visit the Nasher specifically to view cultural heritage, making *A Portrait of Venice* and its digital installations an intriguing, if unexpected, addition to their visit. In 2019, many visitors to *Senses of Venice* may have been moving through the exhibition with goals unrelated to engaging with cultural heritage, but whose curiosity may have been piqued along the way. Furthermore, given the Chappell Gallery's location as a passage between commonly used spaces, it is likely that *Senses of Venice* had far more repeat visitors—those who may have stopped at different parts of the exhibit on different days, or who may have stopped engaging after seeing the exhibition a number of times.[45]

A look at weekly site visits in the 2019 AR installation supports this last hypothesis (fig. 14). After the *Senses of Venice*'s opening, the installation experienced an overall increase in engagement each day.[46] Engagement peaked in the last two weeks of October, coinciding with the annual Family Weekend, which brings students' families and friends to campus for a weekend of festivities. After Family Weekend, the installation experienced a sharp decline in daily site visits with occasional upticks in activity at the beginning and end of Thanksgiving Break and the beginning of Winter

Figure 9. Alina Taalman; An exhibition visitor interacts with the Senses of Venice AR installation; 2019; photograph taken for the use of the project; A visitor holds the iPad in front of herself and views a 3D model of Piazza San Marco and a detail of the Procuratie Vecchie.

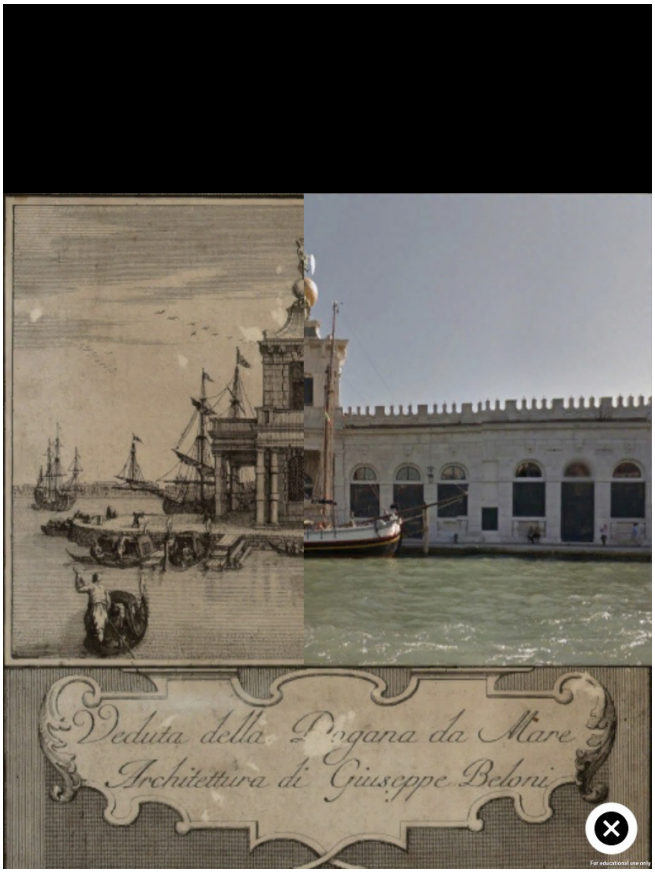

Figure 10. David J. Zielinski; Visitor Interaction in Senses of Venice (2019); 2019; A screen view of the image slider comparing a photograph of a present day Customs House (the Dogana da Mar) with its representation on the Ughi map. As visitors swipe left on the iPad, the photograph is revealed; as they swipe right the Ughi map is revealed.

Break. This overall decline in interaction may be a reflection of the *Senses of Venice*'s visitor population: students, staff, and faculty moving through the space. Increased familiarity with the installation may have led to a commensurate decline in actual engagement; it may have drawn students' and employees' attention at first, but by the end of the semester formed part of their day-to-day backdrop scenery. In addition, while members of the public could access this exhibition, their engagement may have been minimized due to limited public access to Duke's West Campus—only some paid parking and public transportation is available, with neither in close proximity to the library. Another unknown variable is whether visitors engaged with the AR installation more than once, which would reduce the actual recorded total of 1,918.

By contrast, the 2017 AR installation experienced a marked increase in interaction one month after *A Portrait of Venice*'s opening (fig. 13). This increase coincided with a revision to the AR application's interface to include more explicit calls to action using buttons and annotations within Zappar that helped visitors find content and visit additional sites. After this change, interaction remained well above its first month's daily site visits with marked increases during the Thanksgiving and Winter holidays. Again, this difference may have been due to visitor demographics: although the Nasher Museum of Art at Duke University serves the Duke community, it also serves a much broader population in the Triangle Area of North Carolina and beyond. As a consequence, far fewer visitors are likely to have visited the museum multiple times during *A Portrait of Venice*, and far more people overall may have passed through the space on any given day.[47] The increased number during the Winter holidays may be attributed to out-of-town visitors traveling to the Triangle to celebrate holidays with family and friends. Many of these visitors would have purchased a ticket, which encouraged them to maximize their experience, in contrast to the 2019 exhibition that was free of charge.

In trying to further understand the difference in site visits between the two exhibits, a deeper dive into the 2019 exhibition's logs offers some clues. In this analysis, a "session" begins when the application changes from its introductory screen saver (which asks visitors to "Pick up Tablet to Begin") to the main map scanning phase.[48] This change is triggered by a visitor touching the screen or picking up the tablet. A new session, however, would not begin if the visitor handed the tablet to her friend, or if a third person picked up the tablet shortly after its activation. In this described scenario, all three visitors' experiences would have been collected in one session. Following this definition, there were 993 sessions over the course of the exhibition. Notably, in 60% of those sessions visitors performed no further action beyond picking up the tablet or tapping on the screen. That is, they did not scan the map and select a vignette. Why did most visitors stop exploring the application so soon? Is this a characteristic of visitors to AR exhibits in general, or was it unique to *Senses of Venice*? Did visitors need further, more elaborate instructions than those provided in print and within the application? Was a human guide, or perhaps a visitor already using the second tablet, as was observed in 2017, needed to give a "how-to" explanation when visitors were not sure what to do? Unfortunately, even though these questions are worth posing, there is no more granular data for 2017, making comparisons between the two installations limited in this regard.

While the number of daily visits may have greatly differed between the two installations, weekly site visits show a noticeable similarity. As a daily percentage of total weekly site visits, the attendance per day in 2017 and 2019 shows that both installations experienced more interactions during the latter half of the week, from Thursday through Sunday (fig. 14). The *Senses of Venice* AR experienced more site visits overall on Friday and Saturday—perhaps marking times of increased community presence in the library for studying, attending events, and other activities and diminished demands on students for exams and assignment submissions. *A Portrait of Venice* saw its greatest percentage of interactions on Thursdays when the Nasher was open in the evening. In the earlier part of the week, the Nasher was closed on Monday, leading to little interaction—likely only from the developers/authors or museum staff—and experienced similar percentages of interaction as *Senses of Venice* throughout the first half of the week. These similarities in attendance highlight the ways in which the two different exhibition spaces, with their overlapping visitor populations and varying visitor goals, shared similar interaction schedules.

A major difference in the installations and their use may have been in the number of tablets available to visitors. In 2017, two tablets gave a visitor the opportunity to interact with the installation alongside another visitor, or visitors from separate groups may have observed one another. In both cases, visitors could have learned from each other's experiences while simultaneously interacting with the application on separate devices. In the 2019 installation, only one tablet was available, which meant that only one visitor could have held the device at a time. Two visitors from the same group might have experienced the AR application together by passing the tablet back and forth, or one visitor might have observed another's interactions. Someone from another group might have observed these interactions and, if they waited for the first group to finish, could have then interacted themselves, or may have been satisfied with their experience as an observer.

Tablet placement in the AR installations may have also guided visitor interactions. The data reveal that the most commonly visited sites in each installation were among the sites nearest to the tablets' wall mounts. In 2019, the tablet was mounted to the left of the vinyl Ughi map, and

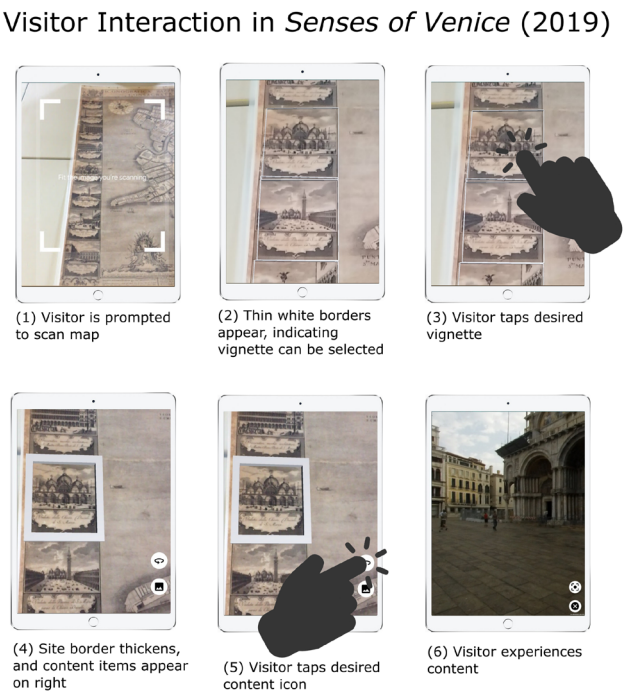

Figure 11. David J. Zielinski; Visitor Interaction in Senses of Venice (2019); 2021; A grid of six iPads showing each step in the AR interaction: (1) Visitor is prompted to scan map; (2) Thin white borders appear, indicating vignette can be selected; (3) Visitor taps desired vignette; (4) Site border thickens, and content items appear on right; (5) Visitor taps desired content icon; (6) Visitor experiences content.

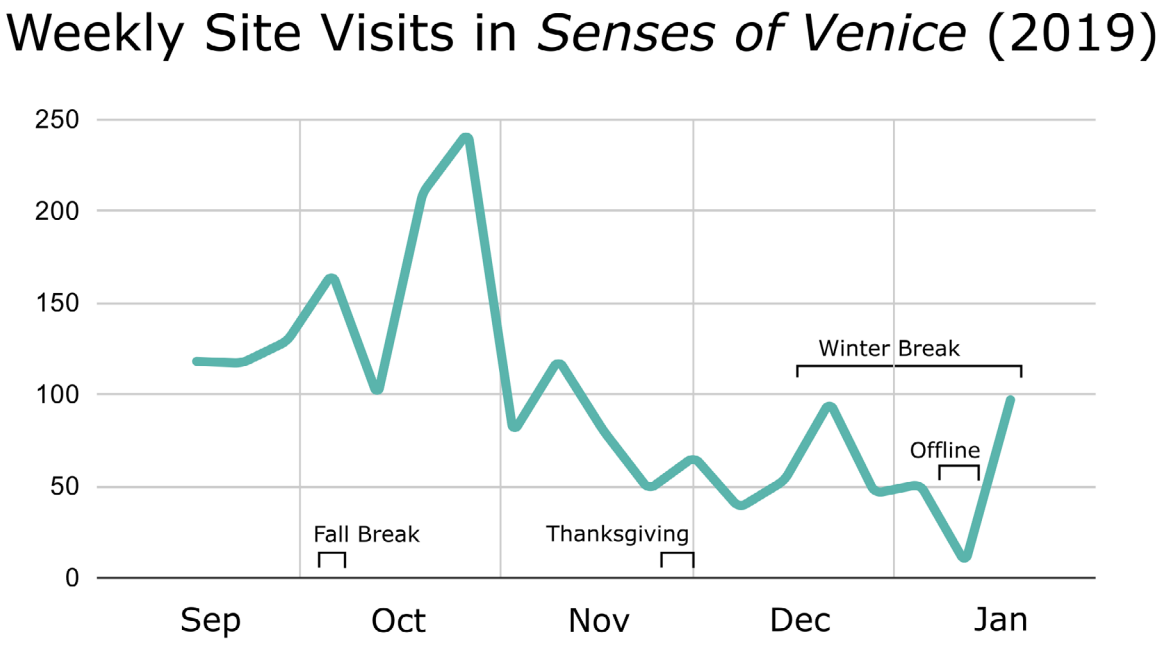

Figure 12. David J. Zielinski; Weekly AR site visits in Senses of Venice (2019); 2021; A bar graph with Y axis representing the raw number of weekly visits and X axis representing the five months during which the exhibition was on view. A blue green line traces the total visits over seven days, Monday through Sunday, for each week in the months. Annotations mark academic holidays (Fall Break, Thanksgiving, Winter Break) as well as a period when the AR installation was offline.

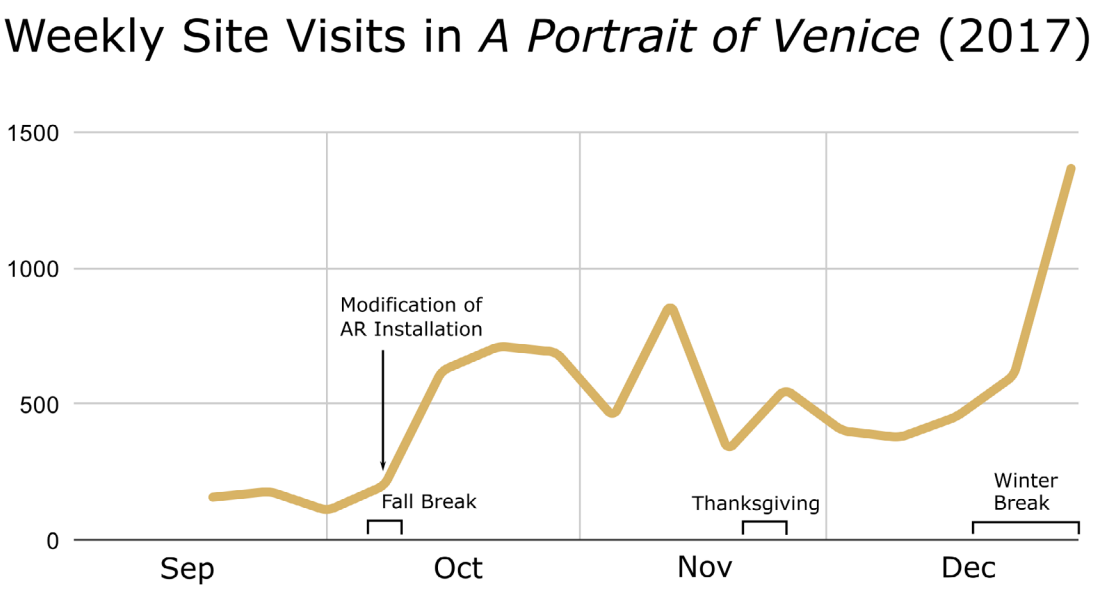

Figure 13. David J. Zielinski; Weekly AR site visits in A Portrait of Venice (2017); 2021; A bar graph with Y axis representing the raw number of weekly visits and X axis representing the five months during which the exhibition was on view. A mustard yellow line traces the total visits over seven days, Monday through Sunday, for each week in the months. Annotations mark academic holidays (Fall Break, Thanksgiving, Winter Break) as well as a point when the AR interface was significantly modified.

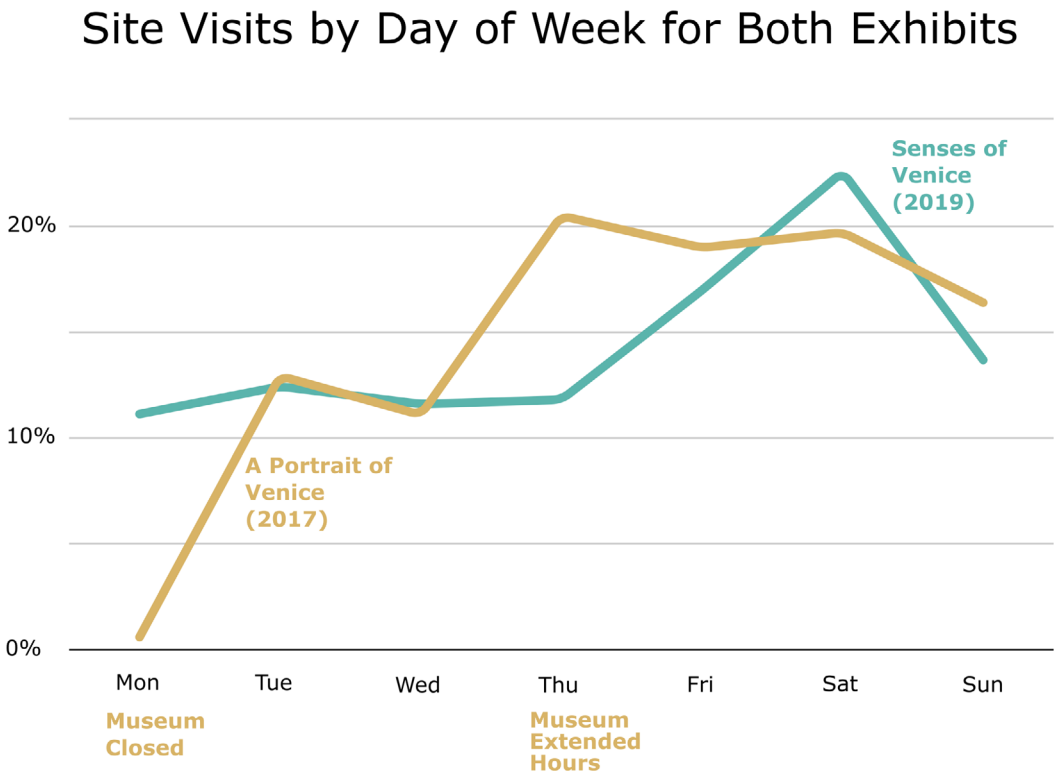

Figure 14. David J. Zielinski; AR site visits by day of the week for both exhibitions; 2021; A bar graph showing the average percentage of AR site visits per day, Monday through Sunday. The Y axis represents the percentages, and the X axis represents the days of the week. A mustard yellow line traces the average AR site visits for A Portrait of Venice (2017) and a blue green line traces the same for Senses of Venice (2019). A mustard yellow annotation below "Mon" (Monday) notes that the museum is closed on this day, and another such annotation below "Thu" (Thursday) notes that the museum has extended hours this day.

Figure 15. David J. Zielinski; Heatmap of AR site visits in Senses of Venice (2019); 2021; A diagram showing the Ughi map with each vignette annotated with the name of the site depicted and a box whose color denotes visit frequency. Brighter red represents a large number of visits; darker red represents fewer visits.

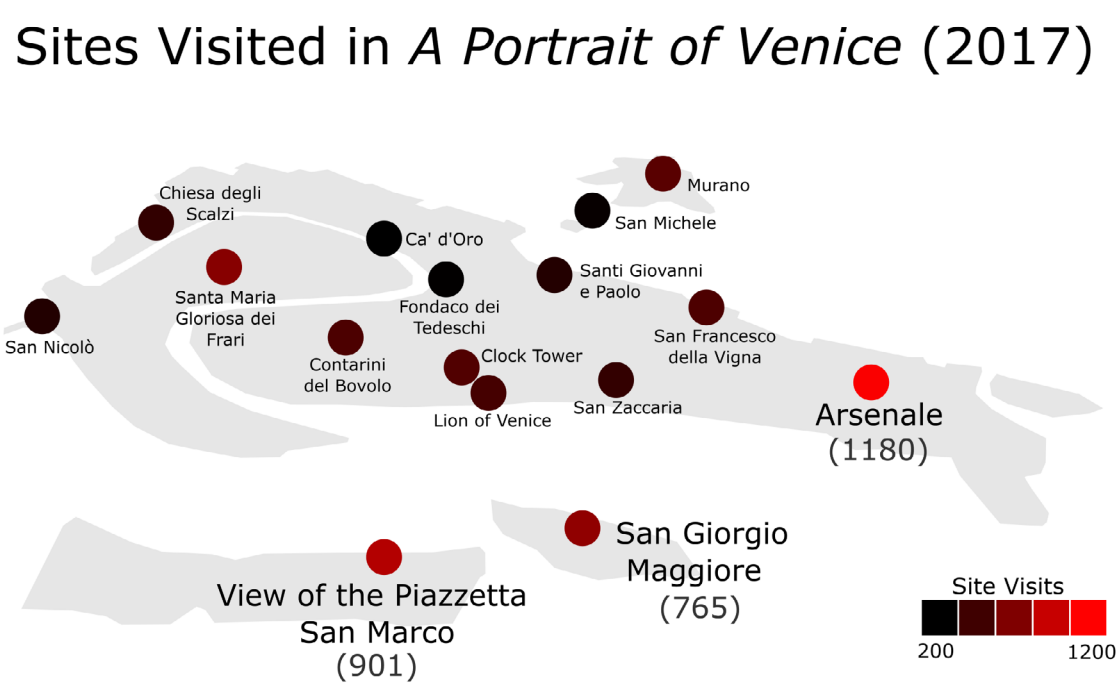

Figure 16. David J. Zielinski; Heatmap of AR sites visited in A Portrait of Venice (2017); 2021; An outline of Venice in gray with AR sites annotated with their site names, number of visits, and a dot whose color represents number of visits: brighter red represents a large number of visits; darker red represents fewer visits.

the most frequently visited sites were the vignettes on the left side of the Ughi map (fig. 15). Coincidentally, two sites heavily featured in the vignettes on that side are San Marco (St. Mark's Church) and its square, which are among the most visited sites in Venice today. In addition, while the left vignettes were physically closer to the tablet's wall mount, these sites may have been more immediately recognizable to visitors.[49]

The 2017 installation saw the most interaction with three sites located along the bottom of the *View*, positioned nearest to the two tablets mounted below the vinyl (fig. 16). Visitors may have chosen sites located closer to the tablets' wall mounts due to convenience. While these are iconic locations within the city (the Arsenal, San Giorgio Maggiore, and the Guidecca), they are not as well recognized as Piazza San Marco. While two of these sites, San Giorgio Maggiore and the Giudecca, featured imagery of Piazza San Marco, with the exception of repeat interactions, visitors would not have known this idiosyncrasy until after scanning them.

Lessons Learned & Next Steps

The developers'/authors' observations and interpretations have coalesced as a set of practices that may be applied to future exhibitions. Regardless of the number of sites visited in each AR session or the number of visitors engaged, the authors/developers remain convinced that these AR installations enhanced the experience of visitors who engaged by drawing connections between present day sites and historic imagery. The AR displays also effectively complemented other digital displays and art historical content curated within each exhibition. As a result, observed conversations and individual contemplation support the use of AR technologies for enriching audiences' experiences of cultural heritage and as content for interactive exhibitions.

Between 2017 and 2019, access to and implementations of AR technologies advanced significantly. A future exhibition could build upon these advancements to ensure further nuanced and enriched experiences. These advancements may not only enhance features for visitor interaction but also present new functionalities and detailed instructions that further support device and application use.[50] In addition, the shift to a custom application built in Unity for 2019's exhibition freed the developers/authors from the limitations of out-of-the-box application features, like those provided by Zappar.[51] In 2019, the team had access to newer technologies in AR Foundation for Unity and the expertise available to build a custom AR application. Therefore, lessons learned in 2017 could be applied to the 2019 edition while also testing new features that expanded the experimental interface. Among these new features was the use of image-based AR that does not require visible markers. This meant that no annotations were printed directly on the vinyl in 2019. Instructions on the tablet screen and the accompanying gallery label offered visitors direction, and annotations that outlined interactive sites on the Ughi map were embedded within the application itself. While the absence of physical annotations enabled a "clean" version of the map to be printed, this visible absence may have resulted in an unintended lapse in visitor interaction. Even though the installation label next to the vinyl provided instructions, it may have been interpreted by some visitors as simply a stitched and reprinted version of the original.

Also added to the 2019 installation were multiple media types per site. In 2017, only one media type (image slider, panorama, video) was offered. The authors' aim in the 2019 exhibition was to provide visitors with a variety of perspectives on the spaces and architecture of the city through multiple forms of digital media. The addition of historic 3D models, in particular, offered visitors an opportunity to further explore and imagine the sites as they once were, particularly for those that have experienced significant change—the now absent church of San Geminiano in Piazza San Marco, for example. Notably, due to limited resources, neither exhibition included textual content. Although many visitors most likely used their personal devices to learn more about a site beyond what may be available in an exhibition, adding more information in future iterations would significantly improve the AR component. To take this a step further, future installations might structure content to encourage historical thinking while, at the same time, building opportunities for educational research concerning visitors' experiences.[52]

The developers/authors also recognize that some visitors' quality of experience with the AR was mediated by their level of comfort with mobile and experimental technologies. Visitors less comfortable with the technologies may not have made the same connections between past and present through the AR. There were known instances in which museum or other staff assisted visitors' interactions when requested, and it has already been stated that few visitors were observed reading the accompanying labels with instructions on use. How might these observations be applied to the physical and digital spaces to accommodate future visitors? One solution may be to provide a brief introduction to the user interface at the beginning of the AR experience. Another may be to train tour guides, in addition to other staff, to facilitate visitors' experiences as part of the exhibition's didactic programming.

An additional consideration is how to make such digital displays more inclusive. Although the installations overall were physically ADA-compliant—the vinyls, labels, and tablets were mounted at levels specified by US federal guidelines—accessible features such as those for visitors with low to no vision and multiple ways to engage with the tablets were not included in 2017 and 2019 due to limited resources (space and funding). While federal guidelines

remain limited regarding digital accessibility, the authors recognize that future installations of this kind must better accommodate visitors who experience the world in different sensory ways—a concern that the augmented reality industry must also address to make both its custom and out-of-the-box platforms accessible from the beginning.[53] These above-mentioned possibilities and considerations, among others, will continue to emerge with increased development and use of AR displays within museums and exhibitions.

The purpose of this article is to present not only some best practices for AR specifically, but also to offer a scalable model for institutions without the infrastructure to support large-scale digital outputs. As exhibitions, *A Portrait of Venice* and *Senses of Venice*, were large-scale, multi-year collaborations that required varying expertise and the coordination of multiple university departments and external institutions. While this section has focused on a number of limitations related to the AR installations for these two exhibitions, the relative privilege of the team requires acknowledgement: international partnerships, access to professional staff who could dedicate even a small part of their time and expertise to technical development and trouble-shooting, an on-campus art museum with resources to support the loan of a major historical artifact, the encouragement of new learning opportunities, and practical access to funding for purchasing equipment and software.[54] The type of AR installations presented here, however, could be standalone, as related to one cultural artifact. They could also, for example, be developed using technology as minimal as QR codes, generated without additional cost for use with museum visitors' mobile devices.[55] Applications such as ZapWorks Studio and Augment, while proprietary, offer no-code interfaces for content creators with minimal technical expertise.[56] Meanwhile Reality Composer and Adobe Aero, also no-code platforms, are freely available to Apple users, and PC users can create mixed reality experiences with little or no code using Microsoft Power Apps.[57] All of the content curated on site—images, videos, models, etc.—could be created using free and/or open-source tools, or gathered from sources licensed under Creative Commons.[58] High-resolution images of artworks needed to produce a vinyl are now more easily accessible from cultural institutions, and these institutions are increasingly open to partnerships with mutual benefits. These suggestions, among others, may enable projects to remain low budget and cost effective, applying principles of minimal computing, while maintaining substantive and qualitative content according to art historical expertise and engaging outputs.[59]

Finally, it bears noting that regardless of a platform's complexity (custom or out-of-the-box), all forms of AR are ephemeral. These experiences, despite the time required to develop them, are temporary. They are built for projects on display for a limited time using tools, often nascent, that rapidly change. Because of these factors, our AR installations have not been preserved as they were originally conceived for future visitors. In order to create longer lasting artifacts, can more stable technologies be used or ones with complementary/supplementary formats? The authors hope to answer this question in an upcoming iterative project that presents an annotated *View* in print form with QR codes, a technology that has changed little since its inception and that has become only more accessible as more people have acquired smartphones.

Conclusion

This article has delineated the ways in which augmented reality offers a temporal bridge between the past and present to connect visitors' own experiences with historic representations of place and space. The consideration of the creation and display of two AR installations as components of the digital art historical exhibitions, *A Portrait of Venice* (2017) and *Senses of Venice* (2019), has offered insights into how such installations can be effective modes of communicating historic relevancy and how they may be structured for effective future installations. As has been demonstrated, such applications enhance visitors' own viewing of historic objects as they offer opportunities for digital interaction and intentionally encourage deliberate and thoughtful looking at the original material artifacts. As AR installations in exhibitions continue to develop, the authors have realized a need to address several important areas that require consideration for future iterations. This may assist the staff of cultural heritage institutions in the following ways: to make AR experiences accessible to visitors with varying abilities and degrees of knowledge, perhaps by creating multiple possible modes for interaction; to continue to understand how visitors engage with AR both as individuals and as groups; to develop and make transparent specific learning goals that inform content selection, structure, and interaction; and, finally, to design installations with both ephemerality and sustainability in mind. As this article has highlighted, AR remains an appropriate, effective, and powerful medium for connecting exhibition visitors to past and present. In the case of the two exhibitions discussed, each AR installation mirrored the material early modern Venetian artifacts in their reliance on interactivity—visual and tactile—as they showcased advancements and technological innovations, from the early modern to the present day.

NOTES

1 The authors would like to thank the institutions and individuals who contributed to the success of the two exhibitions discussed, both curated by Kristin Love Huffman. For the 2017 exhibition, partnership with the Nasher Museum of Art at Duke University and support from Sarah Schroth, Director, and Molly Boarati, Associate Curator of the Nasher, were indispensable. In addition, the loan of the *View of Venice* supported by Rachel McGarry, Curator at the Minneapolis Institute of Art, helped make the exhibition possible. The project received funding from the Samuel H. Kress Foundation, the National Endowment of the Humanities-Mellon Foundation, and the Gladys Krieble Delmas Foundation. The 2019 exhibition benefited tremendously from Andrew Armacost, Meg Brown, and Naomi Nelson of the Rubenstein Rare Book and Manuscript Library, as well as generous support from the Chappell family. We would also like to acknowledge the Department of Art, Art History & Visual Studies, the Digital Art History and Visual Culture Research Lab (formerly Wired! Lab), and Duke Libraries. Finally, we would like to express our appreciation for the insightful suggestions made by the editors of the *DAHJ* and the two anonymous peer reviewers.

2 It should be noted that Jacopo de' Barbari's *View* is a woodcut printed from six carved wooden blocks onto six large sheets of paper. There are three states of the print: 1500, ca. 1519, and late sixteenth century. Ludovico Ughi's *Rappresentatione della inclita città di Venezia* is an engraving printed from twelve copper plates onto paper. There are two known states of this print, 1729 and later 1739 printed by Furlanetto. Select publications related to these two prints include: Juergen Schulz, "The Printed Plans and Panoramic Views of Venice (1486–1797)." *Saggi e memorie di storia dell'arte* 7 (1970): 5–182; Giocondo Cassini, *Piante e vedute prospettiche di Venezia, 1479–1855*. Venice: Stamperia di Venezia, 1971; Juergen Schulz, "Jacopo de' Barbari's View of Venice: Map Making, City Views, and Moralized Geography before the Year 1500." *The Art Bulletin* 60, no. 3 (1978): 425–74; Susan Filter, "Historic Intent: Lodovico Ughi's Topographical Map of Venice: A Large Wall Map as an Historic Document, a Work of Art, and a Material Artifact," *American Institute for Conservation*, vol. 13, (1994); Giandomenico Romanelli, Susanna Biadene, and Camillo Tonini, eds. *A volo d'uccello: Jacopo de' Barbari e le rappresentazioni di città nell'Europa del Rinascimento.* Venice: Arsenale, 1999. Kristin Love Huffman, ed. *A View of Venice: Portrait of a Renaissance City*, forthcoming Duke University Press, 2023.

3 This album of the second state, published in 1739, was acquired by Duke Libraries in 2017.

4 Huffman, Kristin L., "Jacopo de' Barbari's *View of Venice* (1500): "Image Vehicles" and "Pathways of Culture" Past and Present," *Mediterranea*, vol. 4 (2019): 165-214. http://www.uco.es/ucopress/ojs/index.php/mediterranea/article/view/11530/10681.

5 The authors of this article developed the AR displays within the two exhibitions. Huffman, curator of the two exhibitions, collaborated with Jacobs for the creation of the 2017 AR installation, and with Zielinski for the development of the AR installation for the 2019 exhibition. For the purposes of simplifying identifiers within the text, the authors have decided to use "developers/authors" to note our roles as the curator and primary content creators of the Augmented Realities as well as authors of this article. Given the three of us worked closely together within the Department of Art, Art History & Visual Studies at Duke, there has been a fluid continuum regarding the evolution of the AR installation sites, both in content and digital platforms, over the course of the two exhibitions. It should be noted that both exhibitions involved multiple collaborators for the complementary historical and digital content of the additional displays. For the *A Portrait of Venice* exhibition in 2017, this includes the involvement of postdoctoral fellow Ludovica Galeazzo, who was also Assistant Curator, three Duke doctoral students, Iara Dundas, Laura Moure-Cecchini, and Elisabeth Narkin, and a team of undergraduates. For the 2019 *Senses of Venice* exhibition, in addition to the three authors, the exhibition benefited from the contributions of Bradford Lewis, co-curator; colleagues at the University of Padua, including Andrea Giordano, Cristina Zago, and Davide Contiero; and four Duke undergraduate students, Noah Michaud, Angela Tawfik, Daphne Turan, and Mary Kate Weggeland. Finally, both exhibitions benefited from collaboration with international partners CamerAnebbia, specifically Matteo Toro Cellini and Lorenzo Sarti.

6 Sutherland in Bethany Nowiskie and Wayne Graham, "Seeing Swinburne: Toward a Mobile and Augmented Reality Edition of *Poems and Ballads*, 1866," in *Seeing the Past with Computers: Experiments with Augmented Reality and Computer Vision for History*, eds. Kevin Kee and Timothy Compeau (Ann Arbor, MI: University of Michigan Press, 2019), 57.

7 "CAVE" is an acronym of "CAVE Automatic Virtual Environments." See Carolina Cruz-Neira, Daniel J. Sandin, and Thomas A. DeFanti, "Surround-Screen Projection-Based Virtual Reality: The Design and Implementation of the CAVE," in *SIGGRAPH '93: Proceedings of the 20th annual conference on Computer graphics and interactive techniques*, (Association for Computing Machinery, September 1993), 135-142. https://doi.org/10.1145/166117.166134.

8 The CAVE was first demonstrated at the SIGGRAPH conference in 1992. See Cruz et al., "Surround-Screen Projection-Based Virtual Reality," 135. These systems continue to be in use including, until 2019, a CAVE system at Duke known as the Duke immersive Virtual Environment (DiVE) for which Zielinski was engineer.

9 Victoria Szabo, "Apprehending the Past: Augmented Reality, Archives, and Cultural Memory," in *The Routledge Companion to Media Studies and Digital Humanities*, ed. Jentery Sayers (New York: Routledge, 2018), 372. https://hdl.handle.net/10161/19527. See also: Mandy Ding, "Augmented Reality in Museums" (technical paper, Arts Management and Technology Laboratory, Carnegie Mellon University, 2017), https://amt-lab.org/s/Augmented-Reality-in-Museums.pdf.

10 An early example of location-based AR designed for public audiences can be seen in Pokémon Go, a game released in 2016 in which players used their mobile devices (running at least iOS 11 or Android 8.1) to track and capture virtual Pokémon in physical spaces. See https://www.pokemongo.com/.

11 The developers/authors have chosen the term "visitor," the term commonly used in museums and cultural heritage sites, to refer to people interacting with the AR installations over the term "user," which is common among technologists. While "user" might align with ideas of consumption, the authors/developers created the installations not as products to be consumed but as interactive experiences designed to generate thought and emotion among museumgoers. "Visitor" denotes not only those who physically visited the exhibitions, but also those who engaged in mental and virtual "visits" to Venice through exhibition content.

12 "QR" is an abbreviation for "Quick Response."

13 In 2017, major smartphone creators like Apple and Samsung

began releasing AR-capable mobile devices, setting a standard for subsequent device generations and many smartphone makers. These releases coincided with the releases of the massively popular Pokémon Go game and Apple's Animoji feature. See https://www.androidcentral.com/arcore.

14 For a concise description of how AR technologies work, see Markus Wust, "Augmented reality," in *Doing Digital Humanities: Practice, Training, Research*, London: Routledge, 2016, 306.

15 See Kee et al., "History All Around Us: Toward Best Practices for Augmented Reality for History," in *Seeing the Past with Computers: Experiments with Augmented Reality and Computer Vision for History*, Ann Arbor, MI: University of Michigan Press, 2019, 210. The University of Washington's Tech Policy Lab takes these ideas a step further by highlighting how visitors can also use these experiences to connect with others in the AR space. See Ryan Calo, Tamara Denning, Batya Friedman, Tadayoshi Kohno, Lassana Magassa, Emily McReynolds, Bryce Clayton Newell, Franziska Roesner, and Jesse Woo, "Augmented Reality: A Technology and Policy Primer," (technical paper, Tech Policy Lab, University of Washington, 2015), 5. https://techpolicylab.uw.edu/wp-content/uploads/2017/08/Augmented_Reality_Primer-TechPolicyLab.pdf.

16 Jennifer Rich, "Sound, mobility and landscapes of exhibition: radio-guided tours at the Science Museum, London, 1960-1964," *Journal of Historical Geography* 52 (April 2016): 70. https://doi.org/10.1016/j.jhg.2016.02.010.

17 Learn more about *Talking Statues London* at: www.talkingstatueslondon.co.uk.

18 Another Duke-based project on which Jacobs and Huffman collaborated with Ph.D. alumna Elizabeth Baltes, *Statues Speak* (https://projects.dahvc.org/statuesspeak/), was inspired by *Talking Statues London*. *Statues Speak* brought to life bronze statues across Duke's campus through oral storytelling, historical imagery, and 3D models. Visitors scanned QR codes on specially-designed signs placed in front of each statue to access these stories. *Statues Speak* offered campus visitors and community members alike a closer view of statues that were not directly accessible—mounted on plinths, set on traffic islands, or cordoned off—and histories of those commemorated as told from the statues' perspectives.

19 "Smithsonian Brings Historic Specimens to Life in Free 'Skin and Bones' Mobile App," *Smithsonian*, January 13, 2015, https://www.si.edu/newsdesk/releases/smithsonian-brings-historic-specimens-life-free-skin-and-bones-mobile-app.

20 Learn more about the *Chicago 00 Project* at https://chicago00.org/.

21 Learn more about *GHETT/APP* at https://www.guidigo.com/Tour/Italie/Venise/Ghett-APP/iHuiQo6s_kk. Other digital storytelling applications that focus on the history of urban spaces include the suite developed by the *Hidden Cities* team that engage viewers in character-center historical narratives about European cities: https://hiddencities.eu/.

22 Examples of research conducted on AR in museum settings include Jens Keil, et al., "A digital look at physical museum exhibits: Designing personalized stories with handheld Augmented Reality in museums," 2013 Digital Heritage International Congress (Marseille: IEEE, 2013); Yolande Kolstee and Wim van Eck, "The Augmented Van Gogh's: Augmented Reality Experiences for Museum Visitors," IEEE International Symposium on Mixed and Augmented Reality 2011 Science and Technology Proceedings (Basel: IEEE, 2011); Weiquan Lu, et al., "Effects of Mobile AR-Enabled Interactions on Retention and Transfer for Learning in Art Museum Contexts," IEEE International Symposium on Mixed and Augmented Reality 2014 Media, Art, Social Science, Humanities and Design Proceedings, (Munich: IEEE, 2014); C. B. Madsen, et al., "Aspects of What Makes or Breaks a Museum AR Experience," IEEE International Symposium on Mixed and Augmented Reality 2012 Arts, Media, and Humanities Proceedings (Atlanta: IEEE, 2012); and Anne Bationo Tillon, et al., "A day at the museum: An augmented fine-art exhibit," IEEE International Symposium on Mixed and Augmented Reality 2010 Science and Technology Proceedings (Seoul: IEEE, 2010).

23 "Our Mobile App," *National Museum of African American History & Culture,* https://nmaahc.si.edu/connect/mobile/apps.

24 Learn more about *Mapping the Art and Architecture of Renaissance Venice* at https://learn.columbia.edu/index-of-projects and https://projects.mcah.columbia.edu/venice/index.html.

25 Learn more about *The Grand Tour in Venice* at: https://www.thegrandtourinvenice.com/.

26 Learn more about Howard and Moretti's digital supplement to *Sound and Space in Renaissance Venice* at http://djh1000.user.srcf.net/soundandspace/index.php.

27 Bryan Droitceur and William S. Smith, "The Digitized Museum," *Art in America*, September 1, 2016, https://www.artnews.com/art-in-america/features/the-digitized-museum-63201/.

28 Szabo, "Apprehending the Past," 373.

29 Markus Wust, in his chapter on AR in *Doing Digital Humanities*, describes another instance in which present-day images are layered over historical imagery. In this instance, researchers were working with a 1910 booklet titled *Picturesque Victoria*. (309-310)

30 Rich, "Sound, mobility and landscapes of exhibition," 73. Both Venice exhibitions also engaged sound to create a sense of place in the gallery: bringing the sounds of water, church bells, birds, and music into the gallery spaces as a way of engaging visitors in an experience of Venice that is, quintessentially, both visual and aural.

31 The digital *View* was created from photos provided by MIA and stitched together using Agisoft Photoscan (now Metashape) by Nevio Danelon and Edward Triplett.

32 A zoomable version of the *View* is available online courtesy of Duke University Libraries and the Minneapolis Institute of Art: https://idn.duke.edu/ark:/87924/r4k06zz0r.

33 Both the vinyl and tablets were mounted in compliance with American Disabilities Act regulations, though the developers acknowledge that the ability to pick up the tablets or reach all of the annotations may not have been available to every visitor.

34 Zappar is the mobile application developed by ZapWorks (https://zap.works/) to facilitate AR experiences developed using ZapWorks' no-code proprietary technologies, which include their own marker- and image-based tracking technologies and graphical user interfaces for content creation. ZapWorks is designed for content creators with minimal technical or AR expertise.

35 The content developed for the 2019 installation was optimally viewed in a landscape, or horizontal, format. In 2017, and at the time of this essay's writing, Zappar's top menu bar is available only in a portrait, or vertical, format. The result is a slightly awkward interaction in which visitors must engage with the menu at a ninety-degree angle.

36 This format makes sense if one considers the many international visitors to Venice on the Grand Tour who would have purchased the map and had it assembled once back home.

37 The Rubenstein Library specialists scanned the images, and undergraduate Daphne Turan stitched together the image using Adobe Photoshop under the direction of Huffman.

38 The codebase for the *Senses of Venice* AR is not currently public. However, interested readers are encouraged to contact the authors if their research would benefit from accessing the application's code.

39 See https://unity.com/unity/features/arfoundation for an explanation of AR Foundation and how it is used in Unity.

40 This content was gathered and created with undergraduate researchers Noah Michaud, Angela Tawfik, Daphne Turan, and Mary Kate Weggeland.

41 The Nasher also houses a café at which visitors may eat without entering the museum galleries. It is, however, possible for café patrons to access the permanent collection and this exhibition's gallery spaces without paid entry as they exit the museum's main atrium. Such visitors may have found opportunities to engage while waiting for their friends, families, or colleagues.

42 The authors learned how staff and visitors engaged with the AR installation and other digital installations in *A Portrait of Venice* through regular, informal communications with Nasher staff both via email and in person. Mostly, these conversations related to installation maintenance and included anecdotes about their interactions with an installation or their observations of visitor interactions. The authors also observed some of these interactions in the course of maintaining the installations.

43 To better understand which sites were interacted with, and to question why these sites were chosen, the authors examined anonymous visitor data collected by the AR applications in both installations. The data presented in this article cover the length of the respective exhibitions beginning the day after each exhibition's opening event and ending at the end of business on each exhibition's closing day. The authors chose not to include opening event data in the analysis because the project team was on hand during those events to assist visitors, which would have made an impact on the analysis of autonomously performed visitor interactions.

44 Because different applications were used in 2017 and 2019, the data available for analysis varied slightly between the exhibitions. Zappar, the application used for the 2017 exhibition, includes analytic features that gather data about each "scan" of a zapcode with a mobile device's camera. Zappar does not afford content creators control over whether data are collected or how they are collected, nor does Zappar collect personally identifiable information about visitors beyond the type of device they use to interact. While it was possible for visitors to use their personal devices with Zappar, and instructions were provided on a nearby label, no known visitors used their personal device to interact with *A Portrait of Venice*'s AR installation. Because a custom application was built in Unity for *Senses of Venice* (2019), the authors/developers were able to gather and analyze more granular data points both to learn more about visitor interaction and to monitor the application's uptime. As with Zappar, the Unity application does not gather personally identifiable information. In addition, this application was not available for download onto personal devices.

45 The authors do not have empirical evidence to support these hypotheses but can make educated guesses based on their knowledge of the exhibitions' spaces and of the general populations that moved through them.

46 There was one brief decrease in visitor engagement during this time that may be attributable to the university's Fall Break.

47 While the Nasher does not publish overall visitor numbers, its 2018 annual report highlights the nearly 5,948 school children and 2,435 university students who visited during the 2017-2018 academic year. See https://nasher.duke.edu/nasher-annual-report-2018/.

48 Due to the two installations' different digital platforms, the interaction processes differed: the 2019 application required more interaction steps. In the following analysis, the phrase "site visit" is used to describe a single instance of AR interaction in either installation. Because of the additional steps, and because of the available custom analytic tools within Unity, some 2019 data points do not have an equivalent in the 2017 dataset. For example, "session" data, or data about several site visits occurring in close temporal proximity, were collected only in the 2019 application.

49 The one exception may be the vignette that features the Rialto Bridge, which is located along the right side of the map.

50 In 2019, data collection methods about the application's uptime were included in the applications' design, which helped with troubleshooting the few application freezes and crashes that occurred. Over the course of *Senses of Venice*, the AR application was up (functioning as expected) 94.33% of the time. In 2017, due to limitations with the Zappar App, museum staff had to inform the authors/developers of any issues. Thus, there is less information about whether Zappar or the tablets were unavailable for any specific length of time. Instead, they were maintained by weekly and sometimes daily checks.

51 Zappar offers price points for increasing levels of customization, with the most expensive option including access to their SDK (Software Development Kit), which does facilitate the creation of bespoke applications. To fit this installation within the 2017 project budget, and because there was not existing AR programming expertise or time to gain expertise among the team, the authors/developers opted to use an out-of-the-box solution and to create smaller customizations, such as the site buttons, within Zappar's standard application. As previously mentioned, this platform choice also limited our data collection. The authors found in the analytics downloaded from Zappar and in Zappar's documentation that a number of data fields were insufficiently defined. In addition, missing and inconsistent data relating to time of day and other metrics prevented a more granular exploration of visitors' interaction behavior. During the writing of this article, the authors/developers reached out to Zappar for assistance in understanding their data analytics terms. Through several email exchanges, it was revealed that Zappar had done little to maintain the analytics features, had not themselves fully documented analytics data fields, and had lost knowledge about both features and data fields in the period between 2017-2021.

52 Kee et al. describe ways in which game theory and the creation of specific tasks targeting specific audiences (such as adults and children) can not only enhance visitor experience but also open up opportunities for visitors' critical engagement with history. These scholars also highlight the opportunities humanists have to collaborate with social scientists to evaluate the effectiveness of such experiences in order to continue improving cultural heritage AR experiences.

53 For an introduction to accessibility concerns for augmented reality, see the World Wide Web Consortium's overview, https://www.w3.org/WAI/APA/task-forces/research-questions/wiki/Augmented_Reality_and_Accessibility, as well as their XR Accessibility User Requirements: https://www.w3.org/TR/xaur/.

54 It should be noted, however, that in addition to institutional support, the curator was responsible for generating funding through grant writing. While standard practice for the conceptual and art historical content, this proved challenging for the technological components.

55 There are a variety of QR code generators available online. While several good ones are free, there are some that offer paid services for specific features. Some will only allow creators to generate a QR code for a URL. Others will allow the QR codes to be linked directly to various file types or to perform other functions. Here are two that represent this range of features: https://www.qr-code-generator.com/ and https://www.the-qrcode-generator.com/.

56 Learn more about ZapWorks Studio at https://zap.works/ and Augment at https://www.augment.com.

57 Learn more about Apple Reality Composer at https://developer.apple.com/augmented-reality/tools/. Learn more about Adobe Aero's mobile application and beta Mac and Windows desktop application at https://www.adobe.com/products/aero.html. At the time of writing, Aero was free, but this may have changed. Learn more about Microsoft's Power Apps at https://powerapps.microsoft.com/en-us/blog/introducing-mixed-reality-in-power-apps/. Noticeably, all of the applications cited here are proprietary. Many open source AR tools may be free to use but do require some expertise in coding for mixed reality and mobile applications along with knowledge of software such as Unity3D.

58 *Creative Commons*, https://creativecommons.org/.

59 Jentery Sayers, "Minimal Definitions (tl;dr version)," *Minimal Computing*, October 3, 2016, http://go-dh.github.io/mincomp/thoughts/2016/10/03/tldr/.

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