Evaluating geolocated sound to interpret and research historic environments

Workflow for a sonic XR as outdoor place history

SUZIE CLOVES

Department of History, Politics and Philosophy, Manchester Metropolitan University, Manchester, UK, suzanne.cloves@stu.mmu.ac.uk

This article describes workflows established through the creation of a sonic extended reality (XR) which was designed to evaluate the efficacy of geolocated sound as a method for interpreting or researching historic environments. Digital sound layers geolocated upon physical landscapes offered a potent alternative to visual methods for creating XR in outdoor settings. Visual XR, albeit more thoroughly studied, had presented obstacles to deployment in outdoor historic landscapes. GPS-triggered sound could potentially bypass these obstacles as well as facilitating curatorial best practices such as multisensory interpretation and polyphonic storytelling. A heritage-themed sonic XR was created within a historic park to test the suitability of geolocated sound against a range of interpretative requirements and technical challenges. It told the park's origin story through a nonlinear narrative trailscape which comprised audio interviews with communities connected to the park at the time of research, digitized archival oral history recordings of past communities, local music, and historical sound textures. These were deployed as intersecting narrative pathways in order to encourage playful explorative learning by offering multiple potential routes through the history. This design was more or less successful depending on GPS sensitivity versus listener's trajectory versus size of sound area being activated. Using exclusively sonic XR was found to be limiting from an accessibility standpoint. However, geolocated sound as part of a multisensory framework offered significant potential for augmenting historic environments. The project emerged as a useful pilot for a further study using geolocated sound as a research methodology to analyze relationships between place historicity and place attachment.

CCS CONCEPTS • Applied computing~Arts and humanities~Sound and music computing • Applied computing~Education~Interactive learning environments • Human-centered computing~Interaction design~Interaction design process and methods

Additional Keywords and Phrases: augmented reality, visitor experience, trailscape, sonic maps, locative audio, geolocated sound, oral history, sound archive, heritage interpretation, historic environment

1 INTRODUCTION

Geolocated sound– audio files triggered by a listener's arrival at GPS locations – was identified as a potential method for augmenting and interpreting historic environments. It offered a parallel to indoor sonic interpretation methods, such as beacon-activated audio guides, which would operate outdoors where beacons were inappropriate. GPS signal infrastructure was well established and the public already familiar with geolocated sound in the form of GPS navigation systems (satnav), so we were optimistic that the technology could be successfully adapted and readily adopted. This article will detail our approach to designing a trailscape using a publicly available audio-geolocation software platform, and reflect on the medium's capacity to communicate a multivocal history attached to a public historic environment. We hoped to assess geolocated sound against a range of requirements that may be encountered when designing interpretation for an outdoor heritage landscape; these will be detailed in Section 3 (Method). Our core definitions of success were:

- the creation of a GPS-triggered audio trailscape in an outdoor historic environment, with content that was informed by and reflected the place's history and topography
- visitors could self-guide themselves through this trailscape using personal devices such as smartphones, and standard headphones without head-tracking

ACM 1556-4711/2025/4-ART
https://doi.org/10.1145/3731248

- the trailscape's content and visitor experience could be assessed relative to conclusions derived through research
- the outcome could be used as a foundation for further research

Our trailscape was designed to complement work undertaken for Manchester City Council (MCC) following a public consultation (known as *Histories, Stories, Voices*, henceforth HSV) which was commissioned by MCC in response to concern around public statues associated with slavery and colonial history [Manchester City Council 2021]. HSV identified a need to better understand and interpret heritage objects (such as statuary) in Manchester's public realm. MCC therefore commissioned the team at Manchester Metropolitan University to undertake a field survey of the city's public heritage objects and to produce policy recommendations. The trailscape described in this paper was designed to interpret one of the objects identified during the commissioned field survey, to demonstrate how interpretation might be done using emerging technology. The survey detailed 229 public heritage objects in the City of Manchester and permitted broad analysis of Manchester's historic environment. We considered the surveyed objects as keystones for historical narratives which could potentially be geolocated to the landscapes around the objects. From the objects surveyed, we isolated a specific object which was situated in an appropriate place to test geolocated sound against our research criteria, which are detailed in Section 3. The trailscape itself was proposed as an exhibit for Manchester Histories Festival 2022 (MHF), the theme of which was History of Climate Change. We used this theme to narrow down the object list and select a monument to the instigator of a campaign to create a public park to combat urbanization and pollution in 19th century Manchester. The HSV consultation responses conveyed conflicting and polarised public attitudes to demographic representation and colonial themes in public statuary, which informed our ideas around using geolocated sound to design polyphonic place histories. Our subsequent policy report (providing recommendations for MCC) included analysis of existing civic, accessibility and equity frameworks applicable to interpretation of public realm heritage, which also informed our trailscape design. Because HSV was carried out by MCC in collaboration with Manchester Histories, the charity which organised MHF, we used demographic data from the HSV survey to describe a hypothetical target audience for our trailscape. The consequent trailscape [Figure 1] was created using SonicMaps v2[1] [Recursive Arts 2021b] and geolocated within a historic public park known as Platt Fields in Manchester, United Kingdom.

2 USE OF XR AND SOUND IN HERITAGE SETTINGS

Immersive technologies are often categorized as virtual, augmented, mixed, extended, and (perhaps most problematically) real realities. We found it helpful to distinguish primarily between digital and physical, as this allows accurate discussion of objects and contexts regardless of how these are mediated. In the literature, we noted consensus that a virtual reality (VR) was a digital environment that fully occludes the physical surroundings (visually, if not also sonically), whereas augmented reality (AR) was the placement of digital assets into physical settings via mediating technology, such as a smartphone's video feed. Extended reality (XR) is a term typically used to encompass the full spectrum, from AR to VR. In our analysis, we therefore use the term XR when describing the deployment of AR and VR in historic environments and heritage settings. At the outset of this study, XR applications were already used in heritage settings and a substantial body of scholarship had developed, but this had focused predominantly on indoor and visual XR, whereas outdoor settings and audio XR were under-explored. Scholars of XR in heritage contexts argued that it was usually designed to facilitate learning [Ibañez-Etxeberria et al., 2020, Komianos 2020, Maloney and Schofield, 2021, Wilson et al., 2022] but may also help visitors find their way around, or help destination management staff to influence the movement of visitors in order to mitigate crowding [Zhao et al., 2021]. It had also been designed to operate exclusively as an object management tool for staff or researchers [American Museum of Natural History, 2021]. Heritage XR had allowed examination of digital models of physical heritage that was untouchable due to being fragile, in storage, destroyed, underground, or elsewhere [Komianos 2020, Tiddeman et al., 2020, Wilson et al.,

[1] After the research outlined in this paper was completed, the author accepted a temporary paid contract with University of Manchester helping to disseminate outcomes from the SonicMaps EASTN-DC Artist Residency (NOVARS Institute); the residency had originated the geolocated sound platform that was used in our study.

2022]. XR had also been used in heritage scenarios to humanise objects or settings through narrative storytelling or by introducing historic characters [Komianos 2020, Wilson et al., 2022]. It was found to promote and sustain public interest [Cranmer et al., 2021] and had been used to attract attention on social media platforms in order to promote heritage attractions, in particular to new audiences [@Artivive 2022, Wilson et al., 2022]. Heritage XR was also being marketed as a method of accessible remote visiting [@MrsSmithCottage 2022] and had been used to potentiate co-creation between curators and visitors [Mendoza-Garrido et al., 2021]. ACMI's Lens, for instance, let museum visitors assemble their own themed collections of ACMI's assets, thus facilitating ACMI's visitor-led collection philosophy, which aimed to give all visitors authority over the collection and how it was interpreted [ACMI 2022]. Despite some user-resistance to wearable XR tech, research generally found that visitors' response to heritage XR was positive, while the type of XR preferred in heritage settings depended on when and where it was deployed or consumed [Mendoza-Garrido et al., 2021, Maloney and Schofield, 2021, Tiddeman et al., 2020, Wilson et al., 2022, Zhao et al., 2021]. For on-site XR, curators and visitors seemed to prefer a blend of digital and physical (AR) to fully digital immersion (VR) [Komianos 2020] and AR was found to have an "overall positive effect on visitor experience" [Wilson et al., 2022:4]. It was also noted that smartphone-mediated XR was preferred, because this technology was widespread, provided by the user, portable and wireless [Komianos 2020, Wilson et al., 2022], and featured "common parts" such as touch-screen and camera [Maloney and Schofield, 2021:133] which users already understood, and which XR designers could reliably predict and exploit. Further insight into the dominance of visual media in heritage XR was provided by participation in a focus group established by [Arvanitis et al., 2021] to explore XR museum environments. This involved interaction with several extant and emerging XR applications designed for use in museums, all of which heavily focused on visuals and visual accessibility, without considering soundscapes or use of sound to engage visitors or provide non-visual interpretation.

Figure 1: Screengrab of sonic trailscape augmenting Platt Fields Park, Manchester, UK (Image: Suzie Cloves, 2022)

2.1 Limitations of existing XR methods in outdoor historic environments

At the time of review, in 2021-22, general obstacles to use of XR in public settings included the costs of implementation [Cranmer et al., 2021, Komianos 2020], physical constraints such as device processing power or wires limiting user movement [Wilson et al., 2022], users' unfamiliarity with control interfaces, connection problems or download costs, inclusivity barriers such as headsets interfering with turbans or spectacles

[Maloney and Schofield, 2021, Zhao et al., 2021], and questions around data trustworthiness or ownership of digital assets [Katyal 2017]. In outdoor settings, obstacles to XR deployment included limited access to power sources, non-portability of equipment, and the unreliability of triggers used to activate digital assets [Komianos 2020, Tiddeman et al., 2020, Wilson et al., 2022]. XR content could be triggered by vocal commands, handheld controls, tracking the user's position relative to a trigger position using radio signals (indoors) or GPS (outdoors) [Pecino and Climent, 2013], gesture recognition, eye-tracking, or camera recognition of physical images such as QR markers, or landscape objects (markerless recognition) [Tzima et al., 2021]. Many of the methods described required special equipment that could not be left unsupervised or unprotected in outdoor public places. Supervision of XR users and equipment by staff was also necessary for some XRs to function as a user experience at all, due to dependence on a live production team. For instance, although [Benford et al., 2009] found that XR could deliver effective interactive experiences in public outdoor settings, the visitor's journey through the XR was highly orchestrated by live actors or assistants, and dependent on temporary props placed in the public realm. Although this produced a dynamic user experience during the XRs' limited timeframes, it depended on staff to be active throughout the interaction. Assuming that staff were paid, available budget would have been used far more rapidly than with a self-guided experience, restricting access to the XR to those who could afford a ticket and attend during the performance timeframe. Other XR methods became unreliable outside highly controlled scenarios. For example, vocal commands used to trigger media depended not only on accurate voice recognition, which was not ubiquitous, but on being in quiet environments, making them unreliable in crowds or outdoors [Komianos 2020]. GPS was found to be accurate to within five metres, which was too imprecise for accurate superimposition of site-specific digital visual models of buried or lost physical heritage [Pecino and Climent, 2013, Tiddeman et al., 2020, Tzima et al., 2021]. Visual trigger methods, such as images recognised by a camera, were problematic outdoors. To supplement desk research, we created a small visual XR heritage trail which provided first-hand knowledge of the limitations of markerless recognition in outdoor conditions [Cloves 2021]. This involved creating a heritage trailscape that was visually triggered by landscape features. Image recognition of these features depended on contrast between light and shadow, so some patterns were unsuitable, and all became unreliable triggers in sunny or cloudy conditions. Further, we noted that outdoors, seasonal changes (such as to deciduous foliage) could alter the outline of visual tableaux used in markerless recognition. Landscape heritage may lack visible landmarks required for markerless recognition; for instance if it were underground, a lost territory, a collective memory of an event, or the communal reiteration of a route [Fagence 2017, Harte, 2021, MacLeod 2017, Svensson et al., 2020]. Artificial visual markers could be used, but although visitors may be untroubled by markers' effect on aesthetics [Tzima et al., 2021], conservation status may forbid installation of signs needed to display markers, while signs in public landscapes may be unreliable due to vandalism. Weather (such as rain preventing outdoor use of smartphone-mediated AR) was also found to interfere with or potentially damage equipment [Maloney and Schofield, 2021]. Many existing trigger techniques therefore presented obstacles to designing XR for outdoor historic environments.

Consequently, significant heritage risked being overlooked in heritage XR because the majority of XR development had heavily favoured sight and light, in terms of media presented via the XR and how this media was triggered. In the substantial scholarship around XR for heritage contexts, little was said about sound. [Zhu et al., 2022] study of XR at world heritage sites found that (providing XR content matched visitors' ideas of authenticity) visitor satisfaction increased after interacting with XR, but their study only considered images. Similarly, although [Komianos, 2020] identified audio-only XR during a systematic review of XR in heritage settings, this used visual or gestural triggers to launch sonic content. This visual dominance may have been because XR's journey into heritage settings married existing videogame and simulation technology with visual capture techniques developed in archaeology; all prioritised detailed graphic rendering. For instance, in [Komianos, 2020] review of museums XR, 70% of cases used Unity, a widely available videogame engine which easily displayed the output of archaeological methods for rendering digital models of physical artefacts [Autodesk Inc, 2022, Unity Technologies., 2022]. Despite seeming like a natural development, this dependence on visual methods may have limited effective or nuanced deployment of XR in outdoor historic environments. Dependence on visual triggers or use of 100% visual content excluded Blind or Partially Blind (BPB) visitors, and risked excluding social histories that were not associated with visible buildings, objects or imagery. It also limited designers. When developing mobile XR that overlaid digital archaeological models upon a physical ancient burial mound, [Tiddeman et al., 2020] had difficulty achieving correct image placement using visual trigger methods. [Zhu et al., 2022] found that tourists at world heritage sites demanded what they conceived as an authentic appearance for objects presented in visual XR. This could be problematic for any heritage design practitioner wishing to interpret history without high-resolution models of complete visible objects. From newly digitised recordings of spoken working class histories [North West Sound Heritage 2021] to the Ifugao's ancient narrative chants [UNESCO 2022], heritage presented significant reasons to look beyond visual XR.

2.2 Sound and sonic XR in heritage contexts

Using smartphone-mediated geolocated sound to design XR for outdoor historic environments offered the potential to avoid many of the limitations of visual XR. It also provided opportunities to develop heritage interpretation methods that were more inclusive of BPB visitors, and better able to communicate non-visual heritage such as songs, or events that lacked landmarks. It used familiar technology with triggers unhindered by weather, left no mark on the landscape, and offered broader inclusion of people, their histories and heritage. Sound was increasingly valued in heritage practice, to the extent that "the importance of sound" had been recognised by [UNESCO., 2017]. Established archives such as the [British Library, 2021] were funding ongoing sound heritage projects. Outside of XR, scholarship on sonic heritage had focused upon developing methodologies for researching historic sound [Maloney and Schofield, 2021], challenges around archiving and curating ethnographic sound recordings [Lobley, 2014], tensions around the historical authenticity and effect of sounds associated with specific spatial-temporal locations [Jordan 2019, Field 2021], and questions around the social significance of music in working class heritage [Maloney and Schofield, 2021, Johnson 2022]. Specific social history studies ranged from [Muynke et al., 2022] investigation into musicians' memories of acoustics in Notre-Dame after it burnt down, to [Kennerley, 2020] study of the social implications of singing classes for workers in Victorian Manchester, and [Mason, 2004] observations of sound used by aboriginal translators to counter stereotypical heritage narratives. As well as demonstrating increasing interest in sonic heritage, these studies highlighted the importance of considering how historical sounds are related to (or divorced from) their originating physical contexts, while sustaining Social History's tradition of using sound to research counter-cultural and working class narratives.

Technically speaking, sonic augmentation of heritage settings had already been available for decades. For instance, an audio tour cassette played on a Walkman while exploring a historic environment would sonically augment that landscape [Maloney and Schofield, 2021]. Early experiments using sound to augment historic environments used the research team's equipment, such as tablets which had to be carried in backpacks by listeners [Reid et al., 2005]. By the time we began our study, in 2021, the audio could be delivered via listeners' own digital devices which offered location-tracking. Studies of XR in heritage settings found that visitors felt largely comfortable with unfamiliar experiences delivered by smartphone [Maloney and Schofield, 2021], and tended to prefer smartphones compared to bespoke XR equipment [Wilson et al., 2022]. Research that examined the intersection between heritage, sound and XR found sonic XR useful for documenting elements of heritage attached to outdoor landscapes, and noted its potential to improve the accessibility of heritage. For instance,[Veronesi and Gemeinboeck, 2009] explored XR for mapping sonic heritage in landscapes, while others investigated the potential of sound when designing accessible public spaces [Mediastika 2022, Renel 2019]. Eardley and Hutchinson [2020, 2021, 2022] found that sonic XR could facilitate an accessible and enhanced visitor experience in heritage settings specifically. Practice-based studies generated XR environments in order to understand the effect of sonic performances upon listeners within heritage settings, and reflected on implications for researchers and visitor experience designers. For example, Field [2021] created a musical XR to investigate historical composition techniques using digital models of a ruined building's acoustics, noting that a composition's success depended on specific acoustical settings. This raised authenticity issues around recreating historical music in modern contexts. Few studies looked at geolocated audio specifically. However, [Pecino and Climent, 2013] and [Tiddeman et al., 2020] had each demonstrated effective use of geolocated sound as XR within historic settings. There was clearly potential for using geolocated sound to interpret and research historic environments, yet scant scholarship around use of sonic XR in historic environments.

3 METHOD

Our primary objective was to design a trailscape that (1) tested our assumption that geolocated sound would be a good method for augmenting a historic environment, and (2) enabled assessment of how well geolocated sonic trailscapes could overcome the limitations that we identified within visual XR. We were interested in ways to communicate heritage in outdoor communal landscapes, and recognised that these places typically had multivocal (and potentially conflicting) histories attached to them. One core aim was therefore to explore the medium's potential for polyphonic storytelling [see Section 3.3]. Because our trailscape was being designed to demonstrate new ways to interpret public realm heritage objects (as may be required by civic organisations such as MCC), another core aim was to design the trailscape around a keystone object in a public landscape. Other external influences further expanded our remit. The trailscape was accepted as an exhibit for MHF, hence our aim to design it as a visitor experience that aligned with the festival's theme (History of Climate Change). We also developed a relationship with the sound department at MCC's Archives+ in order to explore best practice use of sonic historic objects held by archives, which led to our aim to include archival sounds in the trailscape. Our practice therefore had to address the needs of a variety of stakeholders (e.g., Councillors, communities attached to the trailscape's landscape, festival visitors, sound archivists), as well as allowing us to test a variety of practical considerations. Our objectives and aims for the trailscape and associated output were therefore to:

- Test sonic XR in public historic environment
  - design content and structure that demonstrates reflexivity to a given place's history and topography, as may be required to interpret a place history for visitors or to research its effect in historic environments (as opposed to designing a trailscape that could be geolocated anywhere, such as an array of danceable music that could be toured through a sequence of different parks)
  - incorporate a civic statue or public memorial, to explore efficacy of sonic XR, and to meet requirements such as Manchester Council's need to better interpret public statuary
  - formally assess protected built heritage/archaeology within the place, and translate this into XR content
  - reference visible physical heritage and invisible heritage within the trailscape, to compare the method's efficacy for highlighting visual features versus evoking invisible significance
- Produce method for non-linear multivocal landscape interpretation
  - develop a coherent storytelling structure to represent the polyphony of communal place histories in public landscapes
  - design content and structure in liaison with people and communities associated with a shared place
  - create using a non-linear, asynchronous narrative approach as permitted by geolocated sound software
- Generate recommendations for sound archivists and audio designers
  - explore best practice inclusion of oral histories recorded at diverse sound qualities, as often encountered in sound archives due to historic recording practices, such as use of magnetic tape which deteriorates when stored in suboptimal conditions
  - document best practice inclusion of music, backdrop effects and production sounds (such as audio signposting)
- Deliver a visitor experience for MHF, meeting various requirements
  - adhere to a theme or specific narrative, as may be required by commissioners, such as festival organisers or heritage venues
  - include an area of audio description (literal description of the visual appearance of an object or scenery) for BPB people
  - include transcripts of narrative to accommodate D/deaf people

- consider the fact that visitors may either be exploring on location or listening remotely [see Section 3.1, Table 2, for software's remote listening function]

The trailscape was consequently designed to accommodate our research objectives and associated aims while offering a coherent visitor experience.

3.1 Geolocated sound software platform

Emerging consumer-level platforms were identified that could potentially be used to deploy geolocated sound into the study area. 15 software platforms were identified that had potential to deliver content in the required manner. In order to pick the most functional tool, each platform was scored against weighted criteria that were coded numerically to reflect the importance of each requirement (5=essential, 3=ideal, 1=useful). Weightings were inverted where absence of the criteria was preferred (e.g., software bugs). The platform with the highest score was selected. Table 1 shows the three highest scoring contenders. The following definitions are included for clarity when reading the table:

- author: creator / designer of the geolocated sound content
- developer: creator / designer of the geolocated sound platform / software application
- user: person activating geolocated sound via the platform / software
- reliable tech team: IT technicians retained by the developer to support authors
- bugs: any technical issues encountered while using the software
- user position: the geospatial position of the user while activating geolocated sound on location
- native: app must be installed on the user's device, as opposed to accessed via a web browser

Table 1: Weighted criteria used to score platforms for user-defining geolocated content, as publicly available in June 2021 (showing top three scorers only)

Question	**How to score**	**Echoes**	**Gesso**	**SonicMaps**
Can the app be used to create a geolocated trail and publish it in the UK?	Yes (5) No (0)	5	5	5
Can the app play audio content?	Yes (5) No (0)	5	5	5
Who is responsible for adding content?	Author (3) Developer (0)	3	3	3
Is the app still supported by a reliable tech team?	Yes (1) No (0)	0	1	1
Beyond owning a web-enabled device with a data allowance, does the user have to purchase anything to use the app?	Yes (0) No (1)	1	1	1
Can the content be deployed without a visual trigger image?	Yes (1) No (0)	1	1	1
Can the user activate content remotely without accessing the location?	Yes (1) No (0)	0	1	1
Did you encounter any bugs during testing?	Yes (0) No (1)	0	0	0
Is user position accurate?	Yes (1) No (0)	0	1	1
Can the user see their own position on the app's map in relation to the trail, in case they get lost?	Yes (1) No (0)	0	1	1
Does the content trigger automatically when device arrives at GPS location?	Yes (1) No (0)	1	1	1

Question	How to score	Echoes	Gesso	SonicMaps
Can the app be used without looking at the phone?	Yes (1) No (0)	1	1	1
Is there any cost to the author?	Yes (0) No (1)	1	1	0
Can author add a description and required compliance/governance text?	Yes (1) No (0)	1	1	1
Will our trail be visible to the public via a master map?	Yes (1) No (0)	1	1	1
Is the app browser-based or native?	Browser (1) Native (0)	0	0	1
Can the app function while focus is on another app?	Yes (1) No (0)	0	1	0
Can playback be paused?	Yes (1) No (0)	1	1	1
Does the app respond intelligently to incoming phone calls?	Yes (1) No (0)	0	1	1
Can audio nodes overlap?	Yes (1) No (0)	1	0	1
Can audio amplitude be linked to distance from a position?	Yes (1) No (0)	0	0	1
Can audio node activation depend on activation of another audio node?	Yes (1) No (0)	0	0	1
Does the app enable text to speech?	Yes (1) No (0)	0	0	1
TOTAL SCORE		**22**	**27**	**30**

Alongside scoring platforms for our own use in the author role, field tests of existing smartphone-mediated heritage XR were conducted to gain insight into the user experience offered by different platforms, and to derive effective design approaches, effects and experiences (or things to avoid) from existing designs [see Table 3 in Appendix A.1]. This process involved engaging with a selection of publicly available XRs in the role of a user. For each we produced a ~500 word fieldnote which documented design and narrative approaches employed by the XR's author, how software platform features had been used (compared to the full list of features available within the platforms themselves), any negative effects (such as getting lost, being endangered, narrative dysfunction) caused by design decisions, any software bugs, and the overall effect of all of these upon user experience. For example, the author of the *Dickens: Heart of the City* XR offered well-produced and subjectively interesting content, but failed to make use of a basic capability provided by their chosen software platform (Gesso). This resulted in navigational chaos and consequently a suboptimal user experience. Their XR comprised a linear tour around a winding network of narrow old alleyways in the City of London. Gesso permitted multiple short audio files to be geolocated as stops on a tour, with a map to help the user find each stop. However, the *Dickens* author had instead geolocated one hour-long audio file at a single GPS location (the tour start-point). To find subsequent stops, which were often several minutes apart and separated by complex routes, we had to memorize and follow lengthy strings of complicated wayfinding instructions, which were delivered as part of the narrative. We consequently got lost between many of the stops, and needed to rewind the narrative, but rewinding often crashed the XR. Observations such as these informed a number of design decisions in our own trailscape and are described where relevant in Sections 3.3 and 3.5. Few sonic XRs were available at the time because the technology to create them was nascent. In-situ field tests in London and

Manchester were therefore supplemented by remote activation of XRs situated elsewhere. A four hour session in a fully virtual audio-only digital game designed to be fully accessible for BPB players [Falling Squirrel 2020, Morton 2021] also informed decisions about sound design. Sound archivists working at MMC's Archives+, for whom we were producing recommendations, were already experimenting with sonic XR. Discussions with the Archives+ team informed our list of which geolocated sound platforms could be used, and steered design approaches such as use of field recordings to contextualize archive oral histories in relevant landscapes [Govier, 2021, Jukes, 2021].

The highest scoring platform was SonicMaps v 2.0. This comprised a browser-based content management tool (CMT) which allowed practitioners to anchor audio files to GPS locations via a digital map, and a progressive web app which delivered the audio to listeners as a discreet geolocated sound array, accessed via an URL. Each audio file geolocated in this manner played sound when activated by a listener. Activation occurred if:

- the listener had opened the URL in a browser
- the listener had either pre-downloaded the map's audio files, or was able to stream them in situ
- any conditions [see Table 2 for potential conditions] that affected the audio file's behaviour were met
- the listener either reached the file's geolocation, or dropped an avatar into the file's geolocation on a digital map. (This remote activation was similar to using Google Street View, but the user heard sound instead of seeing streetside photos.)

Table 2: Available properties for sonic areas and arrays of areas geolocated via SonicMaps v2[a]

Property / condition	**Allows practitioner to…**
The following settings affect individual audio files within a discreet array of geolocated sounds:	
Action upon end ["On end"]	determine whether audio file playback will "stop/reset", "pause" or "keep playing" when listener leaves Area.
Action upon exit ["On exit"]	determine whether audio file playback will "stop/reset", "pause" or "keep playing" when listener leaves Area.
Area ["Draw a polygon" / "Draw a circle" icons on map]	draw polygon or circle associated with a GPS location, wherein audio file playback is activated.
Dependency	determine that an Area only becomes visible and activatable once another Area has completed activation.
Distance attenuation	on circular Areas only, determine that audio file's volume decreases as the listener moves away from the circle's centre point. Also causes the sound to loop by default.
Fade-in time	adjust speed with which Area file playback transitions from inaudible to maximum loudness once it is activated
Fade-out time	adjust speed with which Area file playback transitions from maximum loudness to inaudible upon "stop/reset"
Grouping	group Areas for ease of use
Image	append image file to Area
Name	assign identifier to Area (not displayed by default on the public map)
Tags	alphanumeric, user-defined, can be used to filter sound files in content management library
Text	append textual description or transcript to Area
Text to speech	outputs user-defined text in a range of international voices

Property / condition	Allows practitioner to...
Visibility	hide Area from the listener. An invisible Area can still be activated by listener. Does not hide Area from the practitioner in the content management system.
Volume	adjust maximum loudness of individual audio file's playback
The following settings affect the entire discreet array of geolocated sounds:	
Description	visible on the SonicMaps public master-map
Embed code	for embedding the soundscape in a website, for use off-location only
Name	identifies the soundscape on the SonicMaps public master-map
URL	unique online location for sharing the discreet array, for use on- / off- location

[a] [Recursive Arts 2021a]

The SonicMaps platform delivered audio data efficiently, which was important for creating an accessible XR, as some listeners may have had limited access to mobile data. All major sound file formats were accepted at upload and were compressed into a lossy OPUS format, to deliver good sound at low bandwidths, meaning that the trailscape could offer intelligible narrative and a high quality user experience without a substantial mobile data allowance. Associated parameters and restrictions implemented by the software's developer informed the design. Each audio file could be 300MB maximum, up to a maximum playback time of 10 minutes per file. A sound array could comprise unlimited areas of sound, but restrictions were necessary to deliver an optimal user experience. For instance, a large amount of data in a given area risked glitchy playback and could prohibit offline use due to limited storage in the web browser cache. Sounds were thus delivered in small sections, not only to ensure optimal device performance but also to avoid a confusing journey through the trailscape. This reinforced our findings from XR field tests, wherein we got lost having forgotten long strings of verbal navigation instructions given within a single audio file that was associated with a large area [see description of *Dickens: Heart of the City* XR on Gesso in Section 3.1]. A line could be drawn through a sonic map array without associating an audio file with the line, and could either be visible to the listener to aid navigation, or be hidden and used by the practitioner to (a) guide audio placement (b) enable an optional snap to path function, which compensated for mild GPS inaccuracy that occurred near tall buildings due to the way that these can reflect satellite signals, without imposing a linear journey on the listener [Recursive Arts 2021a].

3.1.1 Limitations

Sound areas in an array could be overlapped to interesting effect. When using SonicMaps it was necessary to avoid exceeding four overlaps anywhere in the array to avoid low quality playback on lower-end mobile devices. Overlapping sound areas affected stereo pan; upon deployment we found that SonicMaps automatically distributed two sound areas playing simultaneously with one area slightly towards the left, one slightly to the right. This meant abandoning ideas to play with panning sounds, and led to a conclusion that in future it would be preferable to mix multiple elements into single sound areas to circumvent this distribution pattern, using mono to accommodate hearing differences. Sound spatialization could only occur within the mix when listening to SonicMaps. This affected how listeners could use sounds to navigate the array, because a digital sound's origin could not be located by the listener turning their head. The "distance attenuation" function [Table 2] could be used to make a sound-circle grow louder as the listener neared its centre, permitting a degree of navigation when moving through that area. However, homing in on a sound in this way felt more like playing a game than instinctively spatial navigation-by-sound. A sense of play was welcome, but it was necessary to consider this limitation during sound design and placement. Because the array could be activated on location or remotely, it was also necessary to ensure that comprehension of a given sound was not dependent on the listener's location or physical attitude. This largely affected scriptwriting. For instance, it was important to draw attention to landmarks by saying things like "with your back to Platt Fields, Royle's school is in front of you", rather than "look over there".

3.2 Selecting a historic environment

Our project explored use of geolocated sound to interpret the heritage of a physical landscape, on a specific location. Our trailscape's content therefore had to be site-specific, relating explicitly to the place's historic environment. To learn if geolocated sound could be used effectively to interpret public heritage landscapes, it was also necessary to understand this place as a present-day communal space, to anticipate how the XR might affect or involve people who already used the place. The historic environment for our trailscape was therefore identified using several criteria. First, we confined the theme to History of Climate Change (for MHF) and assumed that our audience demographic would likely be similar to that of respondents to the *Histories, Stories Voices* consultation survey [see Section 1], given that Manchester Histories recruited both groups of people via similar datasets and channels. We then filtered our database of Manchester's public realm objects (generated during our field survey for MCC) to find a keystone object associated with the city's 19th century greenspace activists, who campaigned for the creation of parks to counter pollution and rapid urbanisation during the industrial revolution. This yielded two objects: a bird bath commemorating Queens Park's 1843 founding by parks advocate Malcolm Ross [Hestercombe Gardens Trust 2022] and a seat memorialising William Royle, whose 1907 campaign resulted in Platt Fields Park [Royle 1924]. Both were situated in historic public parks with hard-topped pathways and bus stops nearby, so each were ideal settings for concise heritage trailscapes that could be accessed by listeners with pushchairs, wheelchairs and via public transport. Both monuments were neglected and unattractive [see for instance Royle's memorial in Figure 2], yet represented locally significant people and values, highlighting an interesting tension between perceived value of material heritage versus social legacies associated with historic environments. Platt Fields was geographically close to the research base (Manchester Metropolitan University) whereas Queens Park was not. Royle's campaign was therefore chosen as our topic.

3.2.1 Historical context

William Royle's campaign to save Platt Fields from property developers occurred in 1907, following decades of rapid urbanization which extended the conurbation of Manchester out to Rusholme, a rural village next to Platt Fields which was then a privately owned estate [Landmark Information Group 1848 and 1893, Greater Manchester Archaeological Advisory Service. 2021b-c]. In 1906, when Platt Hall's incumbent Worsley family tried to sell the estate for property development, Royle, a lifelong resident of Rusholme [Royle 1914, Royle 1924], launched a campaign to convince the Corporation of Manchester to purchase the parkland on behalf of the public [Manchester Courier and Lancashire General Advertiser 1907a-e, 1908a-b, Manchester Guardian 1907a-b, 1923 a-b, 1924 a-c, Royle 1907 a-d, 1914:30-37, Royle 1924:65-70, Greater Manchester Archaeological Advisory Service 2021b-c]. Royle's campaign was celebrated as an example of his already famously energetic community work, but also reflected wider socioeconomic trends. Manchester expanded rapidly during its time as a textile boom town. By 1837, parkland immediately north of Rusholme was already an up-and-coming property development [Greater Manchester Archaeological Advisory Service 2021d]. In 1836, property developers advertised speculative shares for land within Rusholme [Greater Manchester Archaeological Advisory Service 2021a], despite there being at that time "no public supply of water in [Rusholme] village, only wells and ditches" [Royle 1914:33]. By the 1860s, there were signs that such speculations might falter. For instance, a cotton famine triggered by civil war in the United States of America was causing textile workers with "pinched faces" to canvass Royle's home street, begging for bread [Royle 1914:36-9]. Manchester's urbanization became unpopular. By the 1880s, Rusholme's residents were lamenting the stench of a polluted brook running through Platt Fields, and the encroachment of railways on all sides [Williamson 1888:17, Royle 1914:12]. As economic decline during the 1870s-1890s reduced appetite for property development, the public were dealing with poor health, industrial pollution and poverty. Public parks were seen as a way to counter health problems caused by industrial pollution [UK Parliament 1848], and Platt Fields was proposed as "breathing space" for Manchester's workers [Manchester Guardian, 1907:12]. The park's construction also offered employment — Royle described how Platt Fields' boating lake was a last-minute addition to ease "acute distress [which] prevailed in the city" [Royle 1914:37]. In Manchester, at least, the creation of public green space seems to have been a popular response to widespread problems. The amount of land set aside for public use in the city increased by 837% between 1890 and 1920 [O'Brien and Wilson 1997]. Following Royle's successful campaign, the Corporation of Manchester obtained £50,000 to purchase the estate, and proceeded over the following twenty years to convert the parkland into a public "pleasure park", with football, cricket, bowling and tennis facilities, "yachting" and paddling pools, an open air swimming pool, a playground, a band stand, and a boating lake [Archives+ 1921, Landmark Information Group 1893 and 1934, O'Brien and Wilson 1997, Greater Manchester Archaeological Advisory Service 2021b-c]. By 2021, only the boating lake remained, with the other facilities converted into a BMX track, community vegetable garden, flower beds and open playing fields, while Platt Hall was operated by MCC as a public heritage venue.

Figure 2: William Royle's humble and poorly maintained memorial (Image: Suzie Cloves, 2021)

3.2.2 Defining the precise trailscape area

A pragmatic approach defined the trailscape's precise area within Platt Fields, because the park's 92.5 acres was too large for the project's scope and timescale. Biographical research into William Royle identified nearby locations that were connected to the narrative, such as Royle's birthplace and first school immediately north of the park. A more confined 37-acre area was therefore selected between the northern boundary of the park (representing Royle's early years) and the memorial seat (representing the end of Royle's life) which was situated half way down the park's eastern boundary. A concise formal heritage assessment was undertaken of this 37-acre area to explore its history. Historic environment records were central to outdoor heritage practice, and a key aim of the project was to explore the potential of geolocated sound for creating heritage XR that was reflexive to historic environments. Our heritage assessment was therefore used to geospatially structure the Platt Fields trailscape, and to inform and structure narrative content. Mapping Royle's biographic landmarks also enabled us to geolocate historical information within a roughly chronological narrative structure, despite working with a non-linear spatial layout [see Section 3.4]. To keep scope manageable and narrative relevant to Royle's chronology and context, the assessment's timespan was restricted to a decade either side of Royle's lifespan. Trailscape layout and content were reflexive to historical locations identified by the assessment. For instance, it was possible to situate the sound of a football game on a football pitch that had since disappeared, and a recording of a brass band on a similarly vanished bandstand. The assessment verified locations mentioned by Royle and his contemporaries in their writing, so excerpts of these texts could be confidently geolocated in association with these places. It also yielded thematically relevant facts about the area's 19th-century transition from rural-agricultural to urban-industrial, which was cited by Royle and his contemporaries as motivating their desire for public greenspace and prompting the campaign for the park. These were therefore used when researching narrative material and structuring the interview questions in order to keep the overall story on-theme.

3.3 Multivocal storytelling in a public landscape

A polyphonic narrative approach was chosen, for several reasons. One of our core objectives was to evaluate geolocated sound as a method for communicating the histories of outdoor places, which were likely to represent a multitude of meanings and memories for different people and communities. It was therefore useful to explore the XR's capacity for multivocal communication. Our heritage XR field tests [see Section 3.1] established that multivocal narrative offered design benefits such as countering monotony and enabling questions to be answered in a conversational way that respected the listener's intelligence. Polyphony was also appropriate for the public park setting and Royle's personal ethos. Various communities had been attached to Platt Fields throughout its history. Royle's community ethos was well-documented, and his campaign to create a public space of communal benefit was central to our story. Immediately after Royle's death, his daughter wrote that Royle "liked to imagine the people playing and resting [in Platt Fields] for generations into the future" [Royle 1924:39], and a hundred years later the park was indeed used for diverse leisure purposes by its associated communities. In other words, the memories, beliefs and knowledge of thousands of people had become attached to Platt Fields' structures. Multiple voices thus seemed academically, creatively and socially correct for the project. Archival and newly recorded interviews with Platt Fields community-members were therefore included, to offer a polyphonic history of the public place, explore the effect of hearing the place's community heritage in situ, and evoke continuity and flux between Royle's time and the present day. Verbal interviews allowed people represented within the place history to speak for themselves, which led us to consider how to evoke voices from the beginning of Royle's lifespan, given that he was born in 1854 [Royle 1924:2] before audio recordings became commonplace. Inventing dialogue for historical people in the pursuit of emotive storytelling risked inserting anachronistic values or invented meaning. Fictitious scripting for historical personas also risked neo-colonial behaviour wherein the practitioner occupied cultural territory that belonged to another — potentially another whose attitudes, beliefs and experiences were never recorded for historians to consult [Chakravorty Spivak 2010]. Voices from the earliest part of the story were therefore drawn from thematically relevant historical texts that were read out by present-day participants. For the present-day voices, 60 community groups and individuals connected to Platt Fields and to the narrative's themes were approached, of which 42 responded, 18 declined or subsequently withdrew or were ruled out due to unresponsiveness. 24 individuals participated in the project, either by being interviewed about the park and narrative themes, or by verbalizing historical texts that were written by people connected to Platt Fields in the 19th century. These various voices were used to tell Royle's story within linear narrative pathways [see Section 3.4], presented as companions to the listener as they moved along, and distributed as nonlinear voxpops to create a sense of encounter with other people sharing the park. Informed consent was supported via preliminary conversations to establish trust and ensure that participants understood a plain language information sheet, understood that participation was optional, and had completed a consent form.[2]

3.4 Narrative structure and spatial layout

Royle's story was told via five narrative pathways covering different aspects of his life, specifically Early Years, Faith & Family, Work & Politics, Campaign for the People's Park, and Health & Death [see Figure 3].

[2] In compliance with Manchester Metropolitan University's Academic Ethical Framework, the research proposal and outreach documentation were approved by an ethics committee prior to engagement with the public.

Figure 3: five narrative pathways in trailscape, showing (1) Early Years (2) Faith & Family (3) Work & Politics (4) Campaign for the People's Park (5) Health & Death (Image: Suzie Cloves, 2024)

The pathways could be encountered in any order, and comprised narrative, interview clips, sound archive material and music, which were sequenced so these could be encountered in either direction. The aim was to design an XR that encouraged a co-creative visitor experience in a historic environment. In other words, we wanted our trailscape to support listeners' agency over their individual explorations of the history in its landscape, by allowing them to reveal information, make cognitive connections, and thus assemble narrative sequences, via their own movement through our material. Further, it was desirable to offer a convenient user experience, because outdoor settings tend to be open and explored in a non-linear fashion, and visitors may have multiple reasons to be in them, such as travelling elsewhere. Visitor satisfaction at heritage sites may be increased by involving visitors in the creation of experiences that respond to visitors' needs rather than imposing pre-determined agendas [Zhao et al., 2021].

Informing visitors was seen as a primary justification for using XR in heritage settings [see Section 2] while Edwards [2021:12] found that the opportunity for "self-authored exploration" provided by XR was an accepted benefit of using XR for education. Geolocated sound arrays therefore seemed useful for historic environment XR because their content could be distributed in a non-linear fashion, allowing visitors to assemble their own meaning and ensure their own comfort by picking their own sequence of encounters with digital and physical objects within the XR. The SonicMaps dependency logic function [Table 2] was therefore not used for our trailscape, as this would have imposed a curated linear journey on the user, even though this would have let us deliver the history chronologically. Consequently, our listeners could choose where (and therefore *when*) they entered and left the history, potentially even hearing different versions of the story by taking different paths through it on different occasions. Because listeners would probably not interact with component sounds in chronological order, the narrative segments were scripted to be meaningful when encountered asynchronously. However, to avoid an overly chaotic visitor experience, the segments were distributed according to an overarching spatial chronology gradient, which was determined by the significance of physical locations in the trailscape. "Earlier" events in the narrative were denser in the north near Royle's birthplace, while "later" events were denser in the southeast by his memorial. The gradient also let us evoke the rural-to-urban transition of the park area using sonic textures, such as horse-drawn traffic in the northeast, versus electric trams in the southwest. We further hoped that the gradient offered play-motivated listeners the chance to work out how the trailscape was organized. Layout was further determined by what Paterson and Richardson [2021] termed a "River" — the densest likely flow of passage through an exhibition, or in our case through the trailscape. Our River was identified using map analysis, site walkovers, and observing how the public already navigate the trailscape area, mainly by using the park's tarmac paths. To support access to the majority of the trailscape's content for people with pushchairs or wheelchairs, we largely confined our River to the tarmac paths, and all five themed narrative pathways adhered to the River. 3mph walks around the River were timed to determine roughly how long the individual audio segments should be.

Linearity inherent to the pathways was counterbalanced by non-linear elements such as scattered voxpops featuring short verbal asides [Figure 4].

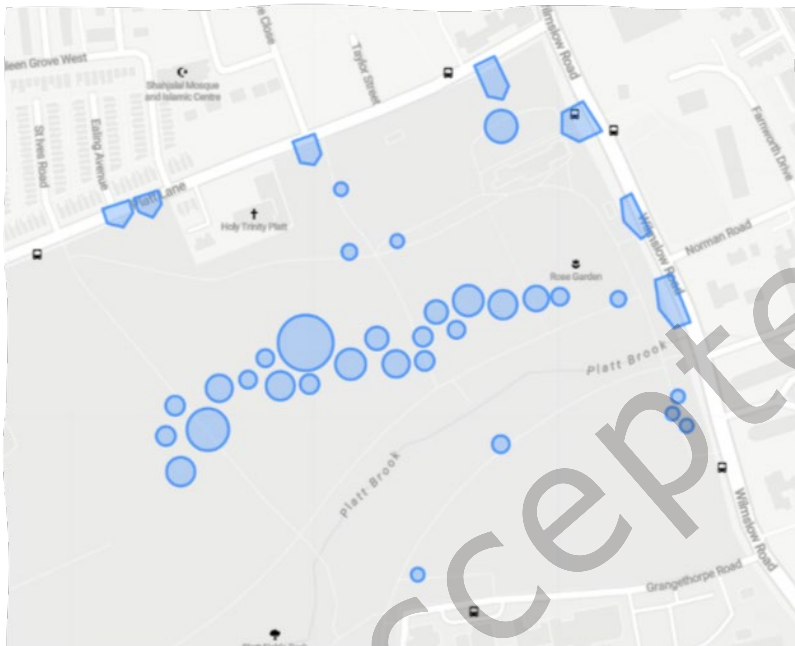

Figure 4: voxpop sound areas isolated from the rest of the trailscape (Image: Suzie Cloves, 2021)

Their content complimented the overall narrative themes in order to support co-creation by allowing listeners to compare and contrast thematically connected material from across the narrative's temporal eras. For instance, one participant was an environmental specialist whose voxpop told listeners that:

> "All of the sewers, they were open sewers. So all of the night and day, y'know, night potties – solid and liquid – went into the rivers. People, when they wanted to relieve themselves, they went in the rivers. Any waste you had from the kitchen – animal entrails, y'know, bloods, bones, whatever – everything went into the river, basically. But then on top of that, at the period we're talking about, in Manchester, you also had the industrial pollution that went in. And heavy industry involves again heavy pollution, both toxic and organic. In fact until recently you would have burning streams or rivers in central Manchester where you'd throw a match and it would catch fire. Mainly because of the methane that's in the water and methane is flammable" – transcript of anonymized speaking participant

We geolocated this near Platt Brook, which ran through the park, and close to another voxpop comprising a different participant reading out a contemporary account from 1888, which romanticised the area's rural past while referencing the polluted state of Platt Brook in the 1880s:

"We can easily imagine how Jordan de Fallowfield and his family would thread their way by the side of the stream — and how gradually would be beaten that path along which, for six hundred years, lovers have whispered the same old story, and breathed the refreshing fragrance of that brook now spoiled for ever. As far as "Hough End", the Manor House of Wythington, the walk was lovely, carpeted by primroses or forget-me-not, fringed with royal fern, bordered with hawthorn, wild rose, honeysuckle and bramble" [Williamson 1888:17]

Lessons learnt during our initial XR field tests of pre-existing visitor experiences [see Section 3.1] also informed layout. For instance, unintelligible narrative was avoided by ensuring that verbal areas did not overlap and that all verbal areas paused playback upon listener-exit. Ambient sounds such as birdsong and footsteps in surfaces such as gravel, wet grass and dry leaves were recorded in Platt Fields and deployed along the narrative pathways. They were also set to be invisible on the visitor map, whereas the narrative areas were visible.

3.5 Access and ethical considerations

The trailscape was produced by a Manchester Metropolitan University Master's student as the practical component of their Public History and Heritage dissertation, so there was no budget available to remunerate focus groups to explore access requirements, nor to hire translators. To inform access considerations, we therefore relied on data from MCC's *Histories, Stories, Voices* consultation, and our own associated recommendations to Manchester City Council [2021], which were made via a 55 page report informed by population data from MCC and the Office of National Statistics, and the following frameworks:

- Equality Act 2010
- Free to Be Strategy 2021-25
- Greater Manchester Clean Air Plan
- HMG Coronavirus Guidance and Support
- Manchester City Council Equality Objectives 2020-24
- Manchester City Council Public Realm Consultation Coding and Analysis Report April 2021
- Manchester City Council Social Value Toolkit for Suppliers 2017
- Manchester Metropolitan University Research Data Management Policy
- Manchester Metropolitan University Research Ethics & Governance
- National Planning Policy Framework 2012
- The Our Manchester Strategy (2016-2025)
- UK General Data Protection Regulation, Data Protection Act 2018
- UN Sustainable Development Goals

Manchester Histories communicated only in English, so the audience was expected to be English-speaking. According to Qpzm LocalStats UK [2021] only 71% of residents in Rusholme (Platt Fields' borough) spoke English as a first language, so use of additional community languages would have been desirable, but was beyond scope, so the trailscape was produced in English only. An exclusively sonic XR inherently risked excluding D/deaf people; we expected that in the real world a sonic map would be used as one component of a portfolio of interpretive material, but a pilot sonic map was tested successfully with a Phonak Compilot signal-booster by a partially Deaf person connected to the project. Transcripts were provided using SonicMaps' built-in text fields, but these were narrow and not ideal for displaying long texts. Although geolocated sound had potential for offering an enhanced experience for BPB visitors, the SonicMaps user interface was not optimized for screen-readers, and a BPB visitor may have needed a sighted person to launch the XR on their behalf, which highlighted a need for future redevelopment of the software in order to develop genuinely inclusive design principles for geolocated audio. To risk-assess material made public in the XR, a sensitivity risk matrix (see Appendix A.2) was designed using risk assessment material provided by the National Library of Scotland [Reeve-Rawlings 2021] and material liable to upset listeners (such as an oral history recounting the death of a comrade during World War One) was prefaced with a verbal warning from the narrator.

3.6 Sound design and production methods

A sparse approach to sound design was chosen over an attempt to fully occlude physical sounds with a simulated historical soundscape. Listeners may be negotiating obstacles, partial blindness, other people and traffic. Occlusion of physical sounds could therefore be unwelcome and even dangerous [Renel 2019]. Full occlusion of present-day physical sounds was also likely to be impossible. The physical soundscape at Platt Fields was dominated by vehicle engines driving past the park and aeroplanes overhead, which were audible even with noise-cancelling headphones, while their subsonic rumbles were felt in the body. Trying to occlude these risked an unsatisfactory experience, with "perceptual cues" generated by "today's environmental surroundings" being liable to cause cognitive dissonance that would spoil the listener's experience and "weaken [rather than establish] a sense of place" [Field 2021:219]. Our aim was to produce an XR that was broadly accessible without specialist equipment, so we assumed that it would be heard through basic earphones and that special conditions (such as instructions specifying volume) could not be imposed upon the listener. Further, the XR could be activated remotely on a home device, where the physical soundscape of Platt Fields could not be heard. White noise and walls of sound would have become especially undesirable in this scenario. A sparser digital soundscape which blended digital and physical ambience therefore offered a successful hybrid experience, as opposed to two competing realities.

Some sounds were designed to help listeners understand what was happening. For instance, footsteps were selected to signpost that someone was about to speak, because it was thematically fitting to give a sense of other people in the park, and because footsteps upon different surfaces embedded the digital narrative into the physical landscape, potentially increasing immersion. The footsteps successfully signalled that speech was imminent or finished. For instance, a listener sent unsolicited feedback stating that they "love the walking sounds in between sections to prompt you to walk on!" [anonymized public listener, 2022]. We observed that immersion seemed more effective when digital footstep surfaces matched the physical surface that was actually underfoot, versus when digital and physical surfaces did not match. For instance, we experienced great immersion by deploying the sound of feet wading through wet grass upon an actual field. However, our immersion was broken wherever the footstep surface did not match the underfoot surface; hearing the sound of one surface while physically walking on a different one seemed to cause cognitive dissonance. We also found that sound areas that were physically close to each other were problematic in areas of lower GPS accuracy, because the software struggled to keep up with the listener moving from one area to the next. Sharply angled polygons led to similar inaccuracy.

Oral history interviews and inherent ambience at Platt Fields were recorded and edited into short audio sequences which were deployed within the study area using SonicMaps. Recordings were made on Zoom H1s using basic lavalier microphones and the H1s' onboard multidirectional microphones. Due to the broad range of volume on location in Platt Fields (which contained sounds ranging from bird song to heavy traffic) the H1s' optional auto-levelling function was disabled because this tended to over-compensate for extremes of quiet and loud, and did not quickly recover from sudden changes between the two. Several of the interviews were recorded in Platt Fields, but to include participants who could not be recorded on location due to the contemporaneous Covid-19 pandemic and other reasons, we also used Zencastr, which enabled multi-track recording online using participants' device microphones. The sound department at Manchester Archives+ provided historical oral history recordings connected to the Platt Fields vicinity.[3] Appropriate music was selected and sourced through desk research and discussions with a regional brass band's historian, a Manchester folk musician-historian, the Manchester Archives+ sound archivist, and the Salvation Army archive. A historical transport timeline was established by reading and listening to accounts of transport around Platt Fields during the late 19th and early 20th centuries, and consulting archive photographs of the area to confirm vehicle types. Library recordings of these vehicle types were sourced from BBC Rewind, an open-source sound library. Platt Fields ambience was recorded to use as bedding sound for the narrative sequences, because field tests indicated that this would help to embed the digital sounds into the physical landscape, aiding immersion.

Spatialization and simulation were key considerations when designing the trailscape. Users would almost certainly be listening on standard headphones without headtracking, which were incapable of detecting ear position in relation to object position [Cook 2002]. A physical object emitting a physical sound may be located by turning the head. In a geolocated sound array, a digital sound may correlate with a physical object in the landscape. For instance, a recording of a church bell chiming could be geolocated around a church. However, the physical origin (two headphone speakers) of the digital church bell would move when the listener turned their head, meaning that stereo pan could not be used to simulate a physical origin for the sound. A listener using SonicMaps could therefore only identify a physical object correlated with a digital sound via techniques such as (1) being told about it within the narrative (2) making the connection themselves by looking around (3) moving around within an area of variable volume wherein the sound was loudest at the physical object [Table 2]. These techniques were built into our design to draw attention to visual landmarks relevant to the narrative.

[3] Permission to use clips of these was sought from necessary rights-holders. All the oral histories (contemporary and archive) were screened to avoid publishing personal data or sensitive information.

For instance, the instruction “Look beyond the first row of houses on the other side of Summer Place — William went to school in that red brick building” was used, whereas in a fully spatialized virtual environment the sound of a school bell could have drawn accurate attention to this particular building [Chinmay 2022]. It should be noted that the instruction to “look” may be problematic for BPB visitors, so inherent descriptive narrative such as “red brick building” was also desirable. Further, given that use of mono output would be preferable versus stereo to accommodate partial D/deafness and hearing differences, Technique #3 (moving around within an area of variable volume) could be considered a more accessible wayfinding method, compared to soundmarks that are spatialized using stereo.

Technique #3 also created a particularly effective sense of arrival and immersion around what became known as the lost bandstand. Here, a ring of trees around a circular pasture in the present-day landscape correlated with a bandstand visible in historic maps and aerial photographs of Platt Fields. Brass was the predominant genre of music popular in North West England at the time, with communities such as churches and collieries represented by their brass bands, and concerts were given in the parks [Archives+ ‘Miss Lally’ (undated), Turnbull 2021]. The lost bandstand therefore offered the chance to explore the effect of using diegetic music (music inherent to the world being evoked and theoretically audible to that world’s inhabitants) within the landscape to illustrate invisible heritage, by situating the sound of a brass band playing at the site. Music was also interesting from a navigational perspective: Ba [2020] found that different types of sound attracted or repelled passers-by, with people drawn by music, but more likely to evade the sound of an industrial fan. Using SonicMaps, it was possible to apply distance attenuation [Table 2] to the volume of music deployed as a circle, so that it was loudest at the centre where the bandstand once stood, and quietest on the perimeter. This simulated the effect of hearing a band playing in situ and would potentially attract a wandering listener to the site. A recording of Hade Edge Brass band was consequently situated in a large volume-attenuated circle centred on the bandstand, and was one of the most effective components of the trailscape, embedding well into the landscape and creating a strong sense of arrival and immersion when approaching the lost bandstand site.

4 CONCLUSIONS AND RECOMMENDATIONS

In reference to our criteria for success [see Section 1], research objectives and aims [see Section 3], we concluded that geolocated sound was a useful method for interpreting and researching outdoor historic environments, providing that the content deployed was carefully chosen and spatially arranged in a fairly uncomplicated way. Although some issues with GPS accuracy prevented precise triggering of sounds, the XR could be activated using standard to low-end smartphones with basic headphones, via a 4G data connection or by preloading the XR via a wifi connection. The method enabled us to deploy an XR that was fully informed by history inherent to its landscape, and which reflected the communal heritage of a public space, via a multivocal narrative structure that was closely connected to the place’s physical topography. We were able to augment a visually unremarkable civic monument with the lively story behind it, using an installation that consulted several relevant communities while complying to a specific theme and meeting a civic priority. The XR successfully intepreted the historic environment without causing any physical damage or material alteration, apart from paper posters advertising the trailscape’s existence, which were temporarily displayed in the park’s visitor centre. We observed that the medium offered potential for drawing attention to visible material heritage in the place, supporting object-based learning while also evoking invisible elements such as community narratives and underground material. For instance, one of our interview participants sent unsolicited feedback about their subsequent exploration of the trailscape, stating that:

> “The way I went round I ended at one of the exits and without realising the last sound bubble I went to was the one about his memorial – it was a bit emotional having just heard the whole life story and then hearing the talk about it being and getting defaced.” [Anonymized participant, 2022]

The trailscape was exhibited at MHF via a customised Bitly URL, which was activated 240 times while live. We did not have access to detailed MHF visitor data, but these engagements implied that the XR made MCC’s existing Archive+ sound assets more available to public audiences than they usually were. We observed that locally produced music and recordings of non-verbal historical sounds seemed effective at evoking the past and encouraging exploration, particularly when geolocated with relevant landscape features. The non-linear narrative structure presented design challenges which we did not fully surmount, but we were able to offer a playful, explorative experience which accommodated visitor needs and offered multiple fresh sequences to anyone making repeat trips through the area. It was necessary to frame oral histories with guiding narrative, recorded ambience and sound effects to ensure that they were embedded in the landscape and useful for the listener. We found it helpful to build present-day landscape sounds into the digital soundscape to aid immersion and create a listening experience that was satisfying whether activating the trailscape on location or remotely.

Although SonicMaps permitted overlapping sound areas and we limited overlaps according to the developer's guidelines, some overlaps affected device performance, implying that minimal overlaps may have been a better approach. Overlapped sound areas were also unexpectedly distributed across the stereo pan (see Section 3.1.1), which could have affected audio for people with hearing imbalances. We therefore suggest addressing performance issues by mixing ambience and narrative together rather than deploying them as separate sound areas. This would enable use of mono sound areas to include people with hearing differences. We also recommend matching digital recordings of underfoot surfaces to the physical surface, because we believe that this more effectively embedded the narrative in the landscape compared to attempting a time-travel effect using disparate surfaces. The recordings of oncoming footsteps were a useful nonverbal way to introduce narrators, but became repetitive during remote activation and where many small sound areas were clustered together; more subtle approaches could be usefully explored. Issues around variable GPS accuracy could be addressed by using compensating features such as SonicMaps' snap-to-path function where appropriate, and through cautious layout design. In low-accuracy places, we recommend avoiding tiny sound areas, introducing space between sound areas, and avoiding sharp angles or serpentine shapes.

One major research restriction was budget, which was nil due to the XR being produced for an unfunded Master's dissertation. A funded project could have included a more comprehensive exploration of listeners' experience of the trailscape, and the effect of the XR upon multiple listeners. The project depended on the generosity of speaking participants who contributed narratives and time to creating the trailscape's content. Listeners' experience was contributed entirely voluntarily via social media channels associated with the project. Funding could have supported the correct remuneration of all these contributors, along with supporting a cohort of dedicated listener participants whose response to the material could have been analysed. This analysis was subsequently conducted as part of a funded follow-up study, the results of which can be accessed by contacting the author.

The most significant limitations were around accessibility. To stay within the scope of a Master's project, our XR was necessarily limited to using existing technology rather than developing a new platform, so was treated as a fact-finding exercise rather than likely to exemplify best practice. As such, the project usefully identified opportunities for improvement, in the software itself and for future research structured to co-produce design principles for geolocated audio. It was clear from the outset that geolocated audio was inherently excluding if used alone, but the limitations of delivering the XR at Master's level underlined the necessity of adequate resources for proper consultation of diverse user-groups, and for co-production of platforms and media. Within the limitations of the study, however, we were able to informally establish that SonicMaps worked with signal-boosting apps, and subsequent to our project the platform's developer introduced geolocated video, potentially enabling a sign-language trailscape. However, fully D/deaf people engaging with our Platt Fields trailscape would have been limited to reading transcripts displayed in a narrow column. This supported our initial assumption that to be truly successful as either an interpretation method or research tool, geolocated sound should sit within a multisensory superstructure of material. Although our XR demonstrated potential for geolocated sound to improve BPB visitor experience, the software platform was not optimised for screen-readers and would need to be developed so that BPB visitors could use it without assistance from a sighted helper. As a result of our findings, the SonicMaps developer subsequently initiated consultation with a BPB focus group in order to redevelop a more accessible platform. Because our project did not have budget to appropriately consult a BPB focus group, the narrative did consider a BPB audience but was constructed by one sighted practitioner with material gathered from sighted interviewees. The project therefore implied significant opportunity for further research wherein geolocated sound was co-designed by and for BPB people, to confirm whether or not the method could enhance BPB visitor experience, and if so to develop best practices. This finding led us to produce a public discussion event with a panel of disability specialists in order to co-produce guidelines for best practice use of sound to support access to heritage [Cloves 2024]. This established the relationships necessary to support co-produced research into the efficacy of geolocated sound to augment landscapes for BPB people. We did establish that geolocated sound could enable remote visiting for people with limited mobility or otherwise unable to reach a site, assuming that this was enabled by the platform used to deploy the sounds. However, careful sound design and scripting would be necessary for this to be a satisfactory visitor experience. For the sake of both BPB and remote visitors, we particularly recommend not assuming that the listener can see physical objects in order to understand the narrative.

As a potential method for communicating polyphonic place histories, the project showed promise but could have further explored its full potential. One individual declined to participate due to fear of public speaking, another because dyslexia affected their ability to read historic text. We therefore recommend that similar projects are adapted so that people could contribute without speaking or reading. Use of multiple community languages would have been desirable but was beyond the scope of the project. Community members provided substantial meaning within the narrative, but its core theme and topic were determined by MCC priorities, the MHF theme, and our research objectives. This was useful because it demonstrated that geolocated sound could be used by heritage practitioners likely to be designing interpretation to a brief, potentially with multiple stakeholder requirements. Nevertheless, the study demonstrated that geolocated sound was an effective way to introduce multiple voices into the historical interpretation of a shared landscape. No inherent quality of the medium itself prevented exclusion of community voices, and voices used were limited only by availability of archive recordings and interviewees. Had we not confined ourselves to a brief, we could have allowed the significance of the place to emerge through co-production from the outset, perhaps allowing meanings, themes, harmonies and dissonance to emerge through the process of creating the material rather than by imposing a particular themed structure. Neither approach was wrong per se, but future projects could further explore the full potential of geolocated sound for creating truly co-produced polyphonic place histories. Our follow-up study, for instance, worked with a residential community to co-establish which sites and stories should be included in a sonic XR as significant heritage, and analysed the effect of this upon listeners' attitudes to the place. It may be fruitful to investigate whether or not XRs created in a similar manner could substantiate nodes of heritage significance attached to places without physical landmarks. This could be useful as a research tool and could inform community-centric planning policy by facilitating assessment and protection of heritage value attached to places without aesthetically or materially valued physical heritage. Future research could also explore geolocated sound trailscapes as heritage artefacts in their own right, perhaps using these to analyse the psychological and social effects of experiencing community histories via this medium.

4.1 Key takeaways

- Dedicate budget to
    - remunerated consultation with diverse focus groups
    - co-production of media content
    - translators where necessary
- Spend time in the landscape before you design any content, to
    - observe how people use and navigate the space
    - document potential hazards
    - map accessibility features such as hard-topped pathways
    - identify sonic features that may affect listening experience, such as loud traffic (potentially disruptive) or parakeets (potentially anachronistic)
- Design digital sound that integrates with physical sound inherent to the place (rather than trying to drown out the physical with a sonic alternate reality)
- Use mono to accommodate hearing differences (and sidestep unexpected stereo effects or lack of spatialized sound)
- Wayfinding is best supported by an accompanying map and short verbal instructions
- Do not depend on the listener to remember long strings of directions
- Consider using changes in volume to aid wayfinding (but remember that quietness affects intelligibility of spoken narrative)
- Allow for the listener to get distracted and respond to their own needs (such as comfort breaks)

- Use verbal cues to draw attention to landscape features
- Make sure that listeners know what you mean even if they cannot see what you are talking about
- Multivocal narratives counter monotony, allow you to answer questions in a naturalistic way, and help to represent communal histories and counter-narratives
- Make sure that participants can contribute to the narrative without reading or speaking
- Weigh up benefits of co-produced content (e.g., inclusivity, public engagement) versus professional voice acting (e.g., listenability, articulate non-verbal voices)
- Only overlap plural narratives if you want to confuse or disconcert the listener
- Narrative is better paused when a listener exits a sound area, than restarting the narrative, which gets repetitive
- Consider using non-verbal recordings (such as birdsong, wind in foliage or traffic noise) to
  - embed narrative into the landscape
  - evoke the place for remote visitors
  - mask poor quality sound (such as hiss) in archival recordings
- Break up your audio into concise segments (but accommodate variable GPS accuracy by using fairly large sound areas with space between them)
- Distance attenuated volume on a circle of sound can be an excellent way to create a sense of arrival at the centre of the circle

ACKNOWLEDGMENTS

The author gratefully acknowledges the contribution of Dr Lisa Gold (Supervision) and Dr Ben Edwards (Writing – Review & Editing). The practical research outlined in this case study was conducted by Suzie Cloves in fulfilment of a degree of Master of Arts in Public History and Heritage at Manchester Metropolitan University, which concluded September 2022.

HISTORY DATES

Received 30 January 2024; revised 7 January 2025; accepted 14 February 2025

REFERENCES

[1] ACMI. 2022. The Lens. Interactive museum collections interface device. Retrieved August 2022 from https://www.acmi.net.au/lens/

[2] American Museum of Natural History. 2021. Collectionscope. Collection metadata visualization interface. Retrieved August 2022 from https://amnh-sciviz.github.io/collectionscope/

[3] Anonymized participant. 2022. Private message to Suzie Cloves, June 2022.

[4] Anonymized public listener. 2022. Private message to Suzie Cloves, July 2022.

[5] Archives+. Undated. Miss Lally. Oral history. GB124.HALLE/62.

[6] ---- 1921. ‘Aerial Views, Platt Fields Park, Rusholme,1921’. Aerial photograph. M67765.

[7] @Artivive. 2022. Promotional Instagram account. Retrieved August 2022 from https://www.instagram.com/artiviveapp/

[8] Kostas Arvanitis, Caroline Jay, Josephy Lampel and Niokolay Mehandjiev. 2021. The XR Museum. Merging physical and virtual interfaces to create eXtended Reality (XR) experiences for cultural audiences. Retrieved January 2024 from https://research.manchester.ac.uk/en/projects/the-xr-museum-merging-physical-and-virtual-interfaces-to-create-e

[9] Autodesk Inc. 2022. Supported file formats. Retrieved August 2022 from https://knowledge.autodesk.com/support/

[10] Meihui Ba, Jian Kang and Zhongzhe Li. 2020. The effects of sounds and food odour on crowd behaviours in urban public open spaces. Building and Environment, 128. 107104. https://doi.org/10.1016/j.buildenv.2020.107104

[11] Steve Benford, Gabriella Giannachi, Boriana Koleva and Tom Rodden. 2009. From Interaction to Trajectories: Designing Coherent Journeys Through User Experiences. Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI ‘09). Association for Computing Machinery. 709–718. https://doi.org/10.1145/1518701.1518812

[12] British Library. 2021. Unlocking Our Sound Heritage. 25 October. Retrieved August 2022 from https://www.bl.uk/projects/unlocking-our-sound-heritage

[13] Gayatri Chakravorty Spivak. 2010. Can the Subaltern Speak. In Can the Subaltern Speak? Reflections on the History of an Idea. Columbia University Press. New York.

[14] Rajguru Chinmay, Giada Brianza and Gianluca Memoli. 2022. Sound localization in web-based 3D environments. Scientific Reports, 12, 1. 22307. https://doi.org/10.1038/s41598-022-15931-y

[15] Suzie Cloves. 2021. Timetracer: Hollywood Park History Hunt. Geolocated media published by PopupView.

[16] Suzie Cloves. 2024. How can we best use sound to support access to heritage? Blog post. Past & Present Society. 1 February. Retrieved July 2024 from https://pastandpresent.org.uk/how-can-we-best-use-sound-to-support-access-to-heritage/

[17] Perry Cook. 2002. Sound production and modeling. IEEE Computer Graphics and Applications, 22, 4. 23-27. https://dl.acm.org/doi/10.1109/MCG.2002.1016695

[18] Eleanor. E. Cranmer, Cathy Urquhart, M. Claudia tom Dieck and T. Jung. 2021. Developing augmented reality business models for SMEs in tourism, Information & Management, 58, 8. 103551. https://doi.org/10.1016/j.im.2021.103551

[19] Julien De Muynke, Marie Baltazar, Martin Monferran, Claudie Voisenat and Brian F.G. Katz. 2022. Ears of the past, an inquiry into the sonic memory of the acoustics of Notre Dame before the fire of 2019. Journal of Cultural Heritage, 56. 130-137. https://doi.org/10.1016/j.culher.2022.09.006

[20] Alison F. Eardley, Hannah Thompson, Anna Fineman, Rachel Hutchinson, Lindsay Bywood and Matthew Cock. 2022. Devisualizing the Museum: from Access to Inclusion. Journal of Museum Education, 47, 1. 150-165. https://doi.org/10.1080/10598650.2022.2077067

[21] B. Edwards, B. B. Edwards, S. Griffiths, F. F. Reynolds, A. Stanford and M. Woods. 2021. The Bryn Celli Ddu Minecraft Experience: A Workflow and Problem-Solving Case Study in the Creation of an Archaeological Reconstruction in Minecraft for Cultural Heritage Education. Journal on Computing and Cultural Heritage, 14, 2. 1-16. https://doi-org.mmu.idm.oclc.org/10.1145/3427913

[22] Michael Fagence. 2017. A heritage "trailscape": tracking the exploits of historical figures - an Australian case study. Journal of Heritage Tourism, 12, 5. 452-462. https://doi.org/10.1080/1743873X.2016.1242593

[23] Falling Squirrel Inc. 2020. The Vale. Digital game. St Catharines, Ontario, Canada.

[24] Ambrose Field. 2021. Hearing the past in the present. In Music and Heritage. Routledge. Abingdon and New York.

[25] David Govier (Project Manager - Unlocking Our Sound Heritage, Manchester City Council). 2021. Emails with Suzie Cloves.

[26] Greater Manchester Archaeological Advisory Service. 2021a. 'Brighton House (Liverpool Victoria Insurance)', Monument Full Report. HER number 8659.1.0.

[27] ---- 2021b. 'Platt Fields', Monument Full Report. HER number 1237.2.0.

[28] ---- 2021c. 'Platt Hall (New Hall)', Monument Full Report. HER number 1237.1.1.

[29] ---- 2021d. 'Victoria Park Hotel', Monument Full Report. HER number 8529.1.0.

[30] Jeremy Harte (Secretary of the Romany and Traveller Family History Society). 2021. Emails with Suzie Cloves.

[31] Hestercombe Gardens Trust. 2022. Queen's Park, Manchester. Retrieved August 2022 from https://www.parksandgardens.org/places/queens-park-manchester-1

[32] Rachel Hutchinson and Alison Eardley. 2020. The accessible museum: towards an understanding of international audio description practices in museums. Journal of Visual Impairment and Blindness, 114, 6.475-487. https://doi.org/10.1177/0145482X20971958

[33] Rachel Hutchinson and Alison Eardley. 2021. Inclusive museum audio guides: 'guided looking' through audio description enhances memorability of artworks for sighted audiences. Museum Management and Curatorship, 36, 4. 427-446. https://doi.org/10.1080/09647775.2021.1891563

[34] Alex Ibañez-Etxeberria, Cosme J. Gómez-Carrasco, Olaia Fontal and Silvia García-Ceballos. 2020. Virtual environments and augmented reality applied to heritage education. An evaluative study. Applied Sciences, 10, 7. 2352. https://doi.org/10.3390/app10072352

[35] Rachel Johnson. 2022. The Agency of Music in Industrial Society: A Comparative Study of the Royal Manchester Institution, Manchester Athenaeum and Manchester Mechanics' Institution, 1834-1860. Journal of Victorian Culture, 27, 1. 97-119. https://doi.org/10.1093/jvcult/vcab052

[36] Pamela Jordan. 2019. Historic approaches to sonic encounter at the Berlin Wall Memorial. Acoustics, 1, 3. 517-537. https://doi.org/10.3390/acoustics1030029

[37] Kirsty Jukes (Rights Officer, North West Sound Heritage). 2021. Emails with Suzie Cloves.

[38] Sonia Katyal. 2017. Technoheritage. California Law Review, 105, 4. 1111-1172. https://www.jstor.org/stable/44630780

[39] David Kennerley. 2020. Strikes and Singing Classes: Chartist Culture, 'Rational Recreation' and the Politics of Music after 1842. The English Historical Review, 135, 579. 1165–1194. https://doi.org/10.1093/ehr/ceaa251

[40] Vasileios Komianos. 2020. Immersive applications in museums: an analysis of the use of XR technologies and the provided functionality based on systematic literature review. International Journal on Informatics Visualization, 6, 1. 60-73. http://dx.doi.org/10.30630/joiv.6.1.708

[41] Landmark Information Group. 1848. 'County Sheet Lancashire', historic map, 1st edition, scale 1:10560.

[42] ---- 1893. 'County Sheet Lancashire', historic map, 1st edition, County Series 1:2500, scale 1:2500.

[43] ---- 1934. 'County Sheet Lancashire', historic map, 3nd revision, scale 1:2500.

[44] Noel Lobley. 2014. Sound galleries: curating the experience of sound and music in and beyond museums. Music in Art, XXXIV, 1-2. 243-255. https://www.jstor.org/stable/90012962

[45] Liam Maloney and John Schofield (eds). 2021. Music and Heritage. Routledge. Abingdon and New York.

[46] Manchester City Council. 2021. Histories, Stories and Voices in Manchester's Public Realm Programme – Update. Retrieved January 2024 from https://democracy.manchester.gov.uk/documents/s26001/Histories%20Stories%20and%20Voices%20in%20Manchesters%20Public%20Realm%20programme%20update.pdf

[47] Manchester Courier and Lancashire General Advertiser. 1907a. 'Platt Hall Estate demanded for public use. 26 July. 12.

[48] ---- 1907b. 'Future of Platt Fields: Deputation to the Lord Mayor'. 30 July.

[49] ---- 1907c. 'Public and Platt Fields'. 1 August. 12.

[50] ---- 1907c. 'Platt Hall Estate: negotiations still proceeding'. 3 September. 6.

[51] ---- 1907e. 'Platt Hall Estate: an unopposed scheme', Manchester Courier and Lancashire General Advertiser, 25 November. 8.

[52] ---- 1908a. 'N.W. Manchester'. 23 January. 7.

[53] ---- 1908b. 'Platt Fields: Rusholme's past worthies'. 25 February. 9.

[54] Manchester Guardian. 1907a. 'The Platt Fields: Ratepayers' Association request'. 24 July. 12.

[55] ---- 1907b. 'Platt Fields: A preservation public meeting', 26 July. 12.

[56] ---- 1923a. 'William Royle of Rusholme'. 7 June.

[57] ---- 1923b. 'The late Mr. William Royle: funeral at Rusholme'. 11 June. 9.

[58] ---- 1924a. 'The proposed memorial to Mr. W. Royle in Platt Fields'. 14 July. 11.

[59] ---- 1924b. 'The William Royle memorial: a sculptor's objection withdrawn'. 15 July. 11.

[60] ---- 1924c. 'William Royle. of Rusholme: a memorial unveiled'. 18 December. 11.

[61] Nicola MacLeod. 2017. The role of trails in the creation of tourist space. Journal of Heritage Tourism, 12, 5. 423-430. https://doi.org/10.1080/1743873X.2016.1242590

[62] Kelly Mason. 2004. Sound and meaning in Aboriginal tourism. Annals of Tourism Research, 31, 4. 837-854. https://doi.org/10.1016/j.annals.2004.03.006

[63] Christina Mediastika, Anugrah S. Sudarsono and Luciana Kristanto. 2022. Indonesian shopping malls: a soundscape appraisal by sighted and visually impaired people. Architectural Engineering and Design Management, 18, 3. 184-203. https://doi.org/10.1080/17452007.2020.1833829

[64] Raynel Mendoza-Garrido, Amaury Cabarcas-Álvarez, Juan José Puello-Beltrán, Ramon Fabregat-Gesa and Silvia Margarita Baldiris-Navarro. 2021. Heritage education experience supported in augmented reality (English translation). Revista Facultad de Ingeniería (Universidad de Antioquia). 99. 52-62. Cartagena, Colombia. https://doi.org/10.17533/udea.redin.20200582

[65] @MrsSmithCottage, Virtual tours make our museum more accessible to those who cannot use ladders. Promotional message. Retrieved August 2022 from https://twitter.com/MrsSmithCottage/status/1554839757284327427?t=l5EWR6uuCLusE212ESmxxw&s=03

[66] Lauren Morton. 2021. Audio-Only RPG The Vale Launches Its Accessible Adventure in August. Rock, Paper, Shotgun (28 July 2021). Retrieved September 2021 from https://www.rockpapershotgun.com/audio-only-rpg-the-vale-launches-an-accessible-adventure-in-august

[67] North West Sound Heritage. 2021. Greater Manchester Oral Histories. Retrieved August 2022 from https://northwestsoundheritage.org/2021/02/02/uap007-greater-manchester-oral-histories/

[68] Jacqueline O'Brien and Zoe Wilson. 1997. 'A building survey of the bowling pavillion in Platt Fields Park: dated 1927; 3rd Year Ground survey project'. December 1997. Via Greater Manchester Archaeological Advisory Service.

[69] Lucie Paterson and Nick Richardson. 2021. The Lens: exposing deeply buried collections to a world of possibility. Online presentation in MuseumNext Digital Collections Summit. 4 October. Retrieved October 2021 from https://www.museumnext.com/events/digital-collections-summit/

[70] Ignacio Pecino and Ricardo Climent. 2013. SonicMaps: connecting the ritual of a concert hall with a locative audio urban experience. International Computer Music Conference Proceedings Volume 2013. Michigan Publishing.

[71] Josephine Reid, Richard Hull, Kirsten Cater, and Constance Fleuriot. 2005. 'Magic moments in situated mediascapes'. Proceedings of the 2005 ACM SIGCHI International Conference on Advances in computer entertainment technology. 290-293. https://doi.org/10.1145/1178477.117852

[72] Qpzm LocalStats UK. 2021. Rusholme Demographics (Manchester, England). Retrieved November 2021 from http://rusholme.localstats.co.uk/census-demographics/england/north-west/manchester/rusholme

[73] Recursive Arts. 2021a. SonicMaps - Frequently Asked Questions. Retrieved September 2021 from https://sonicmaps.xyz/faq.html

[74] Recursive Arts. 2021b. SonicMaps, v2. Software platform. Malaga.

[75] Melissa Reeve-Rawlings. 2021. National Library of Scotland risk assessment document. Sourced via email, 31 August 2021.

[76] William Renel. 2019. Sonic accessibility: increasing social equity through the inclusive design of sound in museums and heritage sites. Curator, 62, 3. 377-402. https://doi.org/10.1111/cura.12311

[77] William Royle. 1907a. 'The Platt Hall Estate', letter to the editor. The Manchester Guardian. 18 July. 12.

[78] ---- 1907b. 'The Platt Fields: More arguments for their purchase'. The Manchester Guardian. 30 July. 14.

[79] ---- 1907c. 'The Platt Fields Estate', letter to the editor. Manchester Courier and Lancashire General Advertiser. 2 September. 8.

[80] ---- 1907d. 'Platt Fields', letter to the editor. Manchester Courier and Lancashire General Advertiser. 9 October. 10.

[81] ---- 1914. History of Rusholme, with a gossipy talk of men and things. William Morris Press. Manchester.

[82] Dora Royle. 1924. William Royle of Rusholme. Sherratt & Hughes. Manchester.

[83] Damian Schofield, Theodore Johnson, Daniel Hufnal, Pranay Chapagain, Sarah Colletta and Paul Lear. 2021. Augmenting cultural experience: evaluating the use of augmented reality technology to enhance the visitor experience at a historic site. Journal of Studies in Social Sciences and Humanities, 7, 2. 129-145. Retrieved July 2024 from https://doaj.org/article/b27ea42d09124637a9ecf26c7b4f9c5a

[84] John Schofield and Ron Wright. 2020. Sonic heritage, identity and music-making in Sheffield, "Steel City". Heritage & Society, 13, 3. 198-222. https://doi.org/10.1080/2159032X.2021.1968227

[85] Daniel Svensson, Sverker Sörlin and Katarina Saltzman. 2020. Pathways to the trail – landscape, walking and heritage in a Scandinavian border region. Norsk Geografisk Tidsskrift - Norwegian Journal of Geography. 75, 5. 243-255. https://doi.org/10.1080/00291951.2021.1998216

[86] Bernard Tiddeman, Jason Cox, Helen Miles, Ben Edwards, Seren Griffiths, Ffion Reynolds, Chris Marshall and Jon Hughes. 2020. Experiencing the Lost and Invisible through Augmented Reality: a case study of Bryn Celli Ddu, Anglesey, Wales. Pre-publication paper shared by authors.

[87] Robert Turnbull (Hade Edge Band leader and historian). 2021. In conversation with Suzie Cloves, 14 December 2021.

[88] Stavroula Tzima, Georgios Styliaras and Athanasios Bassounas. 2021. Augmented reality in outdoor settings: evaluation of a hybrid image recognition technique. Journal on Computing and Cultural Heritage, 14, 3. 1-17. https://doi.org/10.1145/3439953

[89] UK Parliament. 1848. The 1848 Public Health Act. Retrieved October 2021 from https://www.parliament.uk/about/living-heritage/transformingsociety/towncountry/towns/tyne-and-wear-case-study/about-the-group/public-administration/the-1848-public-health-act/

[90] UNESCO. 2017. The importance of sound in today's world: promoting best practices. Technical report. Retrieved August 2022 from https://unesdoc.unesco.org/ark:/48223/pf0000247952

[91] UNESCO. 2022. Hudhud chants of the Ifugao. Retrieved August 2022 from https://ich.unesco.org/en/RL/hudhud-chants-of-the-ifugao-00015

[92] Unity Technologies. 2022. Art Content. Retrieved August 2022 from https://assetstore.unity.com/publishing/submission-guidelines

[93] Veronica Veronesi and Petra Gemeinboeck. 2009. Mapping footprints: a sonic walkthrough of landscapes and cultures. Convergence, 15, 3. 359-369. https://doi.org/10.1177/1354856509105113

[94] Mrs W. C. Williamson. 1888. Sketches of Fallowfield and the Surrounding Manors, Past and Present. John Heywood. Manchester.

[95] Andrew T. Wilson, Helen C. Miles, Frédéric Labrosse, Bernard Tiddeman and Jonathan C. Roberts. 2016. Historical records, archives and photogrammetry. The Historic Environment: Policy & Practice. 7, 1. 25-42. https://doi.org/10.1080/17567505.2016.1142696

[96] Benjamin Wilson, Joshua Hull and Damian Schofield. 2022. An evaluation of the use of audio guidance in augmented reality systems implemented at sites of cultural heritage. International Journal of Multimedia & Its Applications, 14, 2. 1-23. 10.5121/ijma.2022.14201

[97] Celine Zhao Ying Yin, Timothy Jung, M. Claudia tom Dieck and Maria Younghee Lee. 2021. Mobile augmented reality heritage applications: meeting the needs of heritage tourists. Sustainability, 13, 5. 2523. https://doi.org/10.3390/su13052523

[98] Chris Zhu, Man-U. Io, Henrique Fátima Boyol Ngan and Rachel Luna Peralta. 2022. Journal of Vacation Marketing, 29, 2. 242-255. https://doi.org/10.1177/13567667221090990

APPENDICES

A.1 List of smartphone-mediated heritage XR and platforms analyzed at project outset

Table 3: List of smartphone-mediated heritage XR and platforms analyzed at project outset

Producer	Title	Type	Publication data
Aber Trading Limited	Bryn Celli Dhu AR v1.1	Native smartphone app	Aberystwyth. 2020
ACMI (formerly Australian Centre for the Moving Image)	The Lens	Cardboard NFC device	https://www.acmi.net.au/lens/
American Museum of Natural History	Collectionscope	Collection metadata visualization interface	https://amnh-sciviz.github.io/collectionscope/
Artivive	Artivive v3.0.27	Native smartphone app	Vienna. 2021
Baker, Hazel / London Guided Walks	London's Folklore	Content uploaded to Gesso platform	
English Heritage	Stonehenge Audio Guide v2.4.9	Native smartphone app	Swindon. 2021
English Heritage Trust	English Heritage Days Out v3.0.45	Native smartphone app	Swindon. 2021
Google LLC	Google Arts & Culture v8.4.8	Native smartphone app	Mountain View. 2021
Henley, Jon / *The Guardian*	Dickens: Heart of the City	Content uploaded to Gesso platform	

Producer	Title	Type	Publication data
James [Echoes user profile, inactive]	St Dunstans in The East - An Audio Journey	Content uploaded to Echoes platform	
Kalu, Peter	Speak to me, Speke Hall	Content published by PopupView	
Manchester City Council	Heritage Trail (Alexandra Park)	Content hosted by Love Exploring	
Manchester City Council	Postcards from the Past (Platt Fields Park)	Content hosted by Love Exploring	
National Trust	National Trust Days Out v4.3.26	Native smartphone app	Swindon. 2021
New Forest National Park Authority	New Forest National Park Walks v1.1	Native smartphone app	Lymington. 2021
NOVARS	UoM Campus Soundwalk	Content uploaded to SonicMaps platform	
Ordnance Survey Adanac	GetOutside v1.13.4	Native smartphone app	Southampton. 2021
Ordnance Survey Adanac	OS Maps v3.2.0.897	Native smartphone app	Southampton. 2021
Ordnance Survey Adanac	Secret Stories v1.9.0	Native smartphone app	Southampton. 2021
Panetta, Francesca / *The Guardian*	Sound map: the Caledonian Road	Content uploaded to Gesso platform	
Riordan, Jonnie	Monuments	Content uploaded to Echoes platform	
Sparta Digital	Buzzin v2.6.3	Native smartphone app	Manchester. 2018
Steves, Rick	History of London	Content uploaded to Gesso platform	
Swenson, Alasdair / Manchester Metropolitan University ARVR Hub	History Makers v1.93	Native smartphone app	Manchester. 2020
University of Exeter	Hidden Florence v4.5.5	Native smartphone app	Exeter. 2020

A.2 Sensitivity review matrix

Question number	Question	How to score	Clip ID:	*Eg001*	*Eg002*
1	Does information in the recording fall into one or more of these sensitivity flags: domestic violence; eating disorders; race or ethnicity; religious, philosophical or political beliefs; sex life or sexuality; sexual offenses; slavery; suicide; war / violence / Northern Irish Troubles / colonial military activity? **If "yes", use sensitivity warning in associated text or final edit.**	Yes (1) No (0)		*1*	0
2	Are identifiable persons likely to be deceased, or already known to the public? **If "yes", omit questions 3-7 and proceed to question 8.**	Yes (0) No (1)		*1*	1
3	Does the recording contain personal information about one or more identified or identifiable people who are known or likely to be alive?	Yes (1) No (0)		*1*	1
4	Would any of this personal information be categorised as special category data? This is data that reveals a person's: racial or ethnic origin; political opinions; religious or philosophical beliefs; trade union membership; genetic data; biometric data; health conditions; sex life; sexual orientation.	Yes (1) No (0)		*1*	0
5	If one or more identified or identifiable people are known or likely to be alive, should the personal information about them reasonably be considered as confidential?	Yes (1) No (0)		*1*	0
6	If the personal information is confidential, has the need for confidentiality ceased or diminished with the passing of time?	Yes (0) No (1)		*0*	0
7	*If one or more identified or identifiable people are known or likely to be alive, is the personal information about them likely to put them at risk of substantial:*				
	Financial harm (e.g. loss of income or threat to employment)	Yes (4) No (0)		*0*	0
	Physical harm (e.g. personal attack or damage to property)	Yes (4) No (0)		*0*	4
	Reputational harm (e.g. malicious gossip or information that could expose an individual to hatred and contempt)	Yes (4) No (0)		*0*	0
	Distress (e.g. causing severe humiliation, stress or anxiety)	Yes (4) No (0)		*0*	0
	Is there any information that alleges a minor or petty offence?	Yes (4) No (0)		*0*	0
8	Even if an identifiable person is known or presumed to be dead, is the personal information about them likely to put their next of kin at risk of substantial distress? **Does not include "mild annoyance" or feeling that making the recording available is morally wrong.**	Yes (4) No (0)		*0*	0
9	Is there any information that alleges an offence of terrorism or other serious crime, either by means of self-incrimination or incriminating a third party?	Yes (4) No (0)		*0*	0
10	Is there any corporate or trade union information that is still likely to be confidential?	Yes (4) No (0)		*0*	0
11	*Is there any information that is libellous? For example:*				
	A defamatory statement about a corporation or individual, meaning the reasonable person would think worse of them as a result.	Yes (4) No (0)		*0*	0
	A statement that disparages an individual in their business, trade, office or profession.	Yes (4) No (0)		*0*	0
		TOTAL SCORE:		***5***	***6***

Figure 3: Screengrab of sensitivity review matrix (Image: Suzie Cloves, created using content provided by National Library of Scotland, 2021)