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Hearing historic Scotland

Reflections on recording in virtually reconstructed acoustics

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Hearing Historic Scotland: Reflections on Recording in Virtually Reconstructed Acoustics

Introduction:

This article discusses the process and wider implications of a new project by The Binchois Consort which situates an entire CD recording in a virtually reconstructed acoustic. While other projects have sought to capture virtual experiences of one kind or another involving Renaissance polyphony or closely aligned repertoires,¹ we believe our recording is the first complete commercial CD that seeks to reproduce virtually an acoustical experience of a particular space, place, and time: the Chapel Royal of Linlithgow Palace as it stood at the turn of the 16th century. Now a ruined shell, with no roof or windows, clinging to the side of the peel above Linlithgow Loch, it was once the great pleasure palace of the kings and queens of Scotland and the birthplace of James V and Mary Queen of Scots. As a refuge for the royal family between the bustle of the capital, Edinburgh, and the main royal residence in Stirling, the building once resounded to music sung by the skilled musicians of the itinerant chapel royal, surrounded by magnificent decorations and sculptures. Almost none of this—the music or the building’s furnishings—survives.

¹ An early example of something partly analogous was the recording of Obrecht’s *Missa de Sancto Donatiane* by Cappella Pratensis, recorded as part of a physical reconstruction in the Church of St James in Bruges (<https://sites.williams.edu/obrechtmass/>). Related projects have also explored the furnishings of the the Sistine Chapel (see Lisa Pon, Raphael’s “Acts of the Apostles” Tapestries for Leo X: Sight, Sound, and Space in the Sistine Chapel, *The Art Bulletin* Vol. 97, No. 4 (December 2015), pp. 388-408) and Venetian churches (see Deborah Howard and Laura Moretti, *Sound and Space in Renaissance Venice: Architecture, Music, Acoustics*, Yale University Press (February 16, 2010)) Similar physical reconstructions of liturgical events include the ‘Experience of Worship Project’ (<http://www.experienceofworship.org.uk/>), which sought to reconstruct late medieval Sarum liturgy within the context of the reconstructed church of St Teilo and in Salisbury Cathedral. More recent examples which, similarly to our project, have utilised techniques of digital reconstruction have been *Musique et musiciens dans les Saintes-Chapelles, XIIIe-XVIIIe siècles*, concerning the virtually reconstructed acoustic of the Dijon Sainte-Chapelle, with music by Du Fay along with chant plus improvised counterpoint and organ improvisation, presented at an Exhibition at the Musée des Beaux-Arts de Dijon, May 17th – October 13th, 2014; and *ReViSMartin – Renaissance virtuelle de la collégiale Saint-Martin de Tours*, concerning the virtually reconstructed acoustic of the Abbey of St Martin in Tours, using an excerpt from Okeghem’s Requiem (available from <<https://ricercar.cesr.univtours.fr/ReViSMartin/>>). As noted below, the CD is part of a broader project which also combined visual and acoustic reconstruction, but this time as part of a permanent visitors’ experience Linlithgow, and which sought to bring a degree of interactivity to the experience (by allowing the user control over their positioning in the space and to transition between past and present reconstructions) not often seen in similar reconstructive projects.

The project was initially part of the AHRC-funded ‘Space, Place, Sound and Memory: Immersive Experiences of the Past’, which sought to produce two detailed virtual reality reconstructions, one of the chapel of Linlithgow Palace and the other of St Cecilia’s Hall, Edinburgh. The CD project formed one of two central outputs of its impact and engagement follow-on, ‘Hearing Historic Scotland’ – the other being a full virtual reality (VR) headset experience of the chapel reconstruction, designed for permanent installation at Linlithgow Palace. Our purpose here is to give an overview not only of our production process for the CD but also of the broader historical and aesthetic rationale for the project, as well as some initial thoughts as to possible future ramifications. The main focus of the present discussion is on the process of recording the CD, though some consideration of the broader project and, especially, the creation of the Linlithgow Chapel VR experience is necessary, since this was an initial step in the production of the virtual acoustic later used for the CD.²

Our hope was to try to capture something of the experience of listening to a performance in this space in a plausible reconstruction of its state at a particular point in time. An experience designed for CD is, of course, rather different from one designed for VR. The principal difference is the static point of audition and sound which, though robbing us of the chance to explore different positionings, nonetheless affords the possibility of a more accurate acoustic model. In order to give a sense of the audio-visual interaction that we wish to invoke, the CD comes with a downloadable application that allows one to see the spot in which the listener is positioned, as well as the positioning of the singers. This app also allows for transition between hearing a reconstruction of the acoustics of the chapel in the past, and how it sounds today, without its windows or roof, and lacking soft furnishings.

Historical and Aesthetic Rationale:

Before going any further we should offer a caveat: we do not wish to indulge in the romantic notion that what results must therefore be something akin to fifteenth-century experience,

² For more information on the overall VR project, see Kenneth B. McAlpine, James Cook, and Rod Selfridge, ‘Hearing History: A Virtual Perspective on Music Performance’, in ed. Justin Paterson and Hyunkook Lee, *3D Audio*. (Abingdon: Routledge, 2022), 207-27.

whose tone qualities, blend (however that might have been perceived), tempi, phrasing, etc. were in every likelihood a far cry from anything we, half a millennium or more later, can ever reimagine. Yet it is, we think, nonetheless worth considering how this experience, and the results it engenders, might encourage us to think about the kinds of spaces in which such music was initially heard, and what effects that may have had on its aural experience. Crucially, it prompts us to step away from the largely unquestioned notion of the 'best seat in the house' typically engendered by CD recordings (on which more below), and to focus instead on the shifting relationship between the singing and non-singing protagonists of any event involving music, a relationship (or series of relationships) inherent to the circumstances that engendered it.

There can be no doubt that late medieval ecclesiastics understood and exploited the resonances of their buildings. A particularly obvious example concerns the positioning of organs. Dorothea Baumann has pointed out that the invariable placing of large instruments high on walls reflected acoustical concerns: a raised source of sound affords direct transmission of sound to more, and more widely dispersed, listeners; it does this at least partly by allowing access to the flat (and therefore most effective) reflectors of sound above the level of pillars and screens.³ Besides this, and perhaps crucially, it allows simpler, more direct sound reflections from vaults into side chapels and chancel, allowing unimpeded directional access to sound that would otherwise have been interrupted by (much lower) masonry screens and stalls. Besides this, the higher the organ pipes the closer they were to the vault and hence the briefer the time interval between soundwaves traveling directly down to the floor and those bouncing down from the roof, and—as a consequence—the louder the sound perceived on the ground.

The architectural feature of gothic vaulting is clearly conducive to certain acoustical effects. Baumann points out the way in which—in marked contrast to the strongly earthward sound reflections of rounded, romanesque vaults—pointed gothic vaults contain sound waves issuing from the floor.⁴ We will address more specific dimensions and locations shortly, but for now it

³ Dorothea Baumann, 'Acoustics in Gothic Cathedrals: Theory and Practical Experience in the Middle Ages,' in Marcel Pérès (ed.), *Les orgues gothiques*, Actes du colloque de Royaumont, 1995 (Paris: Créaphis, 2000), 37-48.

⁴ 'Acoustics in Gothic Cathedrals', 42-6.

suffices to note that, whatever their other parameters, a very large proportion of ecclesiastical spaces used for music making were vaulted; and while it is in the nature of the written evidence that rather little verbal testimony on these issues has come down to us, we can reasonably expect that singers had a good sense of how best to work with the spaces in which they habitually sang, both for their own benefit and for that of whomever their auditors were expected to be, and wherever they were expected to be standing.

There are some fundamental factors, each easily observable in practice: first, it is in the nature of high-pitched sounds (and hence short sound waves) that they have more pronounced directionality than low sounds, which radiate more broadly; second, loud sounds have a greater propensity to excite disturbing resonances; and third, at least in gothic buildings, due to the reflective nature of stonework, reverberation time is considerably longer at bass frequencies.⁵ Given these circumstances it is no surprise that most cases of known vocal forces in polyphonic ensembles pit a relatively large number (usually the whole complement) of choirboy voices against single performers on each of the lower parts.⁶ For the same reasons it makes sense that the undivided Blockwerks of late-medieval organs combine small numbers of pipes for lower pitches with (often very) large numbers for higher ones. Resonant spaces favour high pitches; hence it is similarly unsurprising that it usually works best, when configuring singers in a concert in the nave of a church, to put the lower voices in the middle of an arch shape facing directly out at the audience, with the higher voices at the side and pointing slightly inwards.

At the heart of our initial project was an intention to reintroduce several aspects of performance that we felt have often been overlooked in historically-informed performance projects, in particular a sense of space and place being an integral dimension of performance, and the multimodality that this entails. Fifteenth-century liturgical music took place as part of a

⁵ On the latter point see Raf Orłowski, 'Acoustics and Architectural Form', in Deborah Howard and Laura Moretti (eds.), *Architettura e musica nella Venezia del Rinascimento* (Milan: Bruno Mondadori, 2006), 48, plus figure 8, p. 47. Orłowski suggests a reverberation time of up to 10 seconds at 100 Hz

⁶ Though it should be noted that nuns' choirs tended to do the opposite, with a greater number on the lower parts. This seems likely to reflect the greater weight of higher ranges in adult female voices. Our thanks to Laurie Stras for this observation.

multimedia spectacle;⁷ an auditor moving through a sacred space unencumbered by pews would have been surrounded by a richly decorated world of wall paintings, tapestries, and sculptures: decorative, instructive, and devotional. As Kirkman and Weller attest, such sculptures, lit by the variable natural light afforded by windows plus the play of flickering candle- and torch-light, could for the viewer be transformed into living stone; in parallel fashion the saints similarly enlivened by polyphonic decoration would be animated by sound. As they argue, drawing on the near-contemporary theories of Roger Bacon, the eye of the beholder did not just passively regard the object on which it gazed, but was instead united with it, assimilating something of its essence. ‘The result thus resonates closely with the idea of a “charged space” of meaning conjured by contemplation, one in which what—to our eyes—appear as miracles of transformation or simply metaphors may to at least some in the late Middle Ages have been conceived as much more palpable.’⁸ Certainly, contemporary accounts of religious experiences often narrate events as though they happened in real-time, with the viewer very much in the direct presence of the events as they unfolded, as attested, for example, by Julian of Norwich:

I saw His swete face as it was drye and blodeles with pale deyeng, and sithen more pale, dede, langoring, and than turned more dede into blew, and sithen more browne blew, and the flesh turnyd more depe dede. For His passion shewid to me most properly in His blissid face, and namly in His lippis. There I saw these four colowres, tho that were aforne freshe, redy, and liking to my sigte. This was a swemful chonge to sene, this depe deyeng, and also the nose clange and dried, to my sigte, and the swete body was brown and blak, al turnyd oute of faire lifely colour of Hymselfe on to drye deyeng.⁹

⁷ Andrew Kirkman and Philip Weller, ‘Music and image/image and music: the creation and meaning of visual-aural force fields in the later Middle Ages,’ *Early Music*, 45/1, (2017), 55–75.

⁸ Ibid.

⁹ *Julian of Norwich, The shewings of Julian of Norwich*, ed. G. R. Crampton, TEAMS Middle English Text Series (Kalamazoo, MI, 1993), ch.16, 59. Quoted in Susan Arvay, ‘Private passions: the contemplation of suffering in medieval affective devotions’ (PhD diss., Rutgers University, 2008), 86. For a more fully developed consideration of this point see Andrew Kirkman, ‘Image, Music and Lived Reality in Fifteenth-Century Midlands Alabaster’ in Julia Boffey (ed.), *Performance, Ceremony and Display in Late Medieval England*, Harlaxton Medieval Studies 30 (Donington, Lincs.: Shaun Tyas, 2020), 255-72.

Pre-modern performance was therefore a fully-immersive, perhaps even overwhelming, multi-modal sensory experience. Sight and sound here work reciprocally to full effect, with the faculty of smell also brought evocatively into play by incense, burning wax and tallow and even by the sensation of prevailing humidity.

The manner in which the contemporary performance space was used is also alien to our modern experience of listening in a concert hall or to a CD, the listener having more agency to explore its bounds, contingent upon the role and location of each actor in the scene. Other projects, in more analogic fora, have explored the nature of the music's audibility for different people experiencing the same act of devotion.¹⁰ The affordances of VR allow us to explore this effect at greater leisure and with enhanced control, tracing the acoustical impact of audition in various positions, of movement during performance, and even allowing for exploration of positions that are in reality impossible (or at least wildly impractical): even when, for example, occupying the same physical space as a particular singer one cannot share that singer's experience of resonance, both external and (particularly) internal.

One other vital dimension of performance concerns its acoustic setting. Composers of the past clearly knew the kinds of spaces for which they were writing their compositions, knowledge that informed many of their compositional decisions, which thereby emphasised certain spatial characteristics and looked to exploit the nature of their acoustic effects; and while court chapels were of course often itinerant, the vast number of pieces composed for performance for particular individuals would have been written for specific performance in specific locations—side chapels, altar chapels and other fixed chantries.¹¹ Similarly, today there is broad consensus, at least as demonstrated by the preferences of commercial record producers, as to the kinds of (typically generous) performance acoustics that work well for late medieval and

¹⁰ See 'The Experience of Worship' project, accessible at www.experienceofworship.org.uk

¹¹ Even in the case of music that travelled beyond the site of its original performance, to be performed in different areas and indeed by different ensembles, we contend that medieval polyphony would predominantly have been performed in relatively small spaces, decorated with soft furnishings.

renaissance polyphony, though some scholarly opinions have begun to challenge these.¹² Our project sought to explore reconstruction of some of these past acoustics as accurately as possible, with a view at least partly to illuminating, by contrast, modern conceptions of performance practice. As we will discuss below, our reconstructed acoustic in the end offered something unexpected and, we think, potentially propitious.

In seeking to recapture these aspects of performance—the multimodal, the peripatetic, and the acoustic—we turned to VR technology. By drawing on the abilities of VR to embody music performance in a virtual environment that encourages a sense of presence and agency in the listener, we contend that it is possible to bring together key aspects of the experiential dimensions of live performance with the reproducibility and accessibility of a recording. In the same way that the architectural and acoustic spaces of historic performances comprised mechanical structures for creating immersive sensory experiences, modern VR technology provides a digital mechanism to do likewise. Using this technology, we are able to explore reconstruction of now-lost performance spaces, and in doing so, we also problematise the assumption that many of the still-extant performance spaces that we might wish to use today have retained configurations that would have been familiar to our musical forebears.

The stakes for this kind of reconstructive exercise are high. It has often been maintained that recorded music cannot, in any definitive sense, be held to reconstruct how that same music would have sounded in the pre-recording past. But that basic truism should not blind us to the fact that the performances and recordings we experience today nonetheless pre-condition the sounding possibilities we are able to entertain; and to take that one step further, preconceptions of ‘how a piece of music sounds’ inevitably inform, however strenuously we might resist them, our written as well as our sounding interpretations.

Anyone who accepts this basic tenet would presumably also accept that there is much to be gained from thinking about where we are positioned (actually or notionally) as we listen to the

¹² Anna Zayaruznaya, ‘Intelligibility Redux: Motets and the Modern Medieval Sound’, *Music Theory Online*, 23/2 (2017).

music of the past: in what building, or part of a building, and whether as auditor (whatever that may mean), singer, director or—in the case of a liturgical event—celebrant, dean or subdeacon, and so on. In the case of a project in virtual-sounding reconstruction such as ours, one has no choice but to consider these variants, and it is that consideration that informs our discussion here.

Perhaps the most pervasive assumption we make about the sound of recordings (so pervasive, in fact, that it rarely even enters our consciousness) concerns the position of the notional ‘listener’. We shall refer to this position by reference to the assumption that typically underpins it: the ‘best seat in the house’. Echoing our comment above, for recordings of late medieval music that seat is typically some distance from the source of the sound, allowing for the kind of ‘olde-worlde’ bloom that lies at the root of comments made recently by Anna EZayaruznaya.¹³ Unfortunate casualties of the said bloom for late medieval polyphony are the contrapuntal complexities that attract many of us to the music in the first place and—the source of Zayaruznaya’s particular criticism—the words.

We make the above points in a deliberately general way, hopefully allowing a sufficient basis for the more particular considerations engendered by the ‘Hearing Historic Scotland’ recording project. As a result we aim to demonstrate why we consider the exercise to have been valuable, and to open up a space to consider possible future ramifications. Our next stage, therefore, is to offer an introduction to the process of reconstruction which underpinned the project.

The Process of Virtual Reconstruction:

Our discussion must necessarily begin with our virtual reconstruction of the visual and architectural representation of the space, even if this is merely an invisible underpinning to our CD project. The reconstruction began life as highly detailed LIDAR scans of the site—the chapel at Linlithgow Palace, the great pleasure palace of the Kings and Queens of Scotland—produced in partnership with Historic Environment Scotland. LIDAR uses a rotating laser gun to take measurements of the building, accurate to a fraction of a millimetre, which allows for a

¹³ Ibid.

minutely detailed model, consisting of hundreds of thousands of polygons, to be produced of the building as it currently stands (see image one).¹⁴ However, this level of detail is computationally extremely expensive, and not conducive to giving sufficient processor power to compute acoustics at the same time.¹⁵ Thankfully, however, it is not necessary for an accurate acoustic model. We therefore streamlined the results by vastly reducing the number of polygons whilst maintaining the accurate structural details required for modelling (see image two). Our LIDAR scanning also recorded high-resolution photographic images which could be overlaid on the structural model, to give it its required texture (see image three).

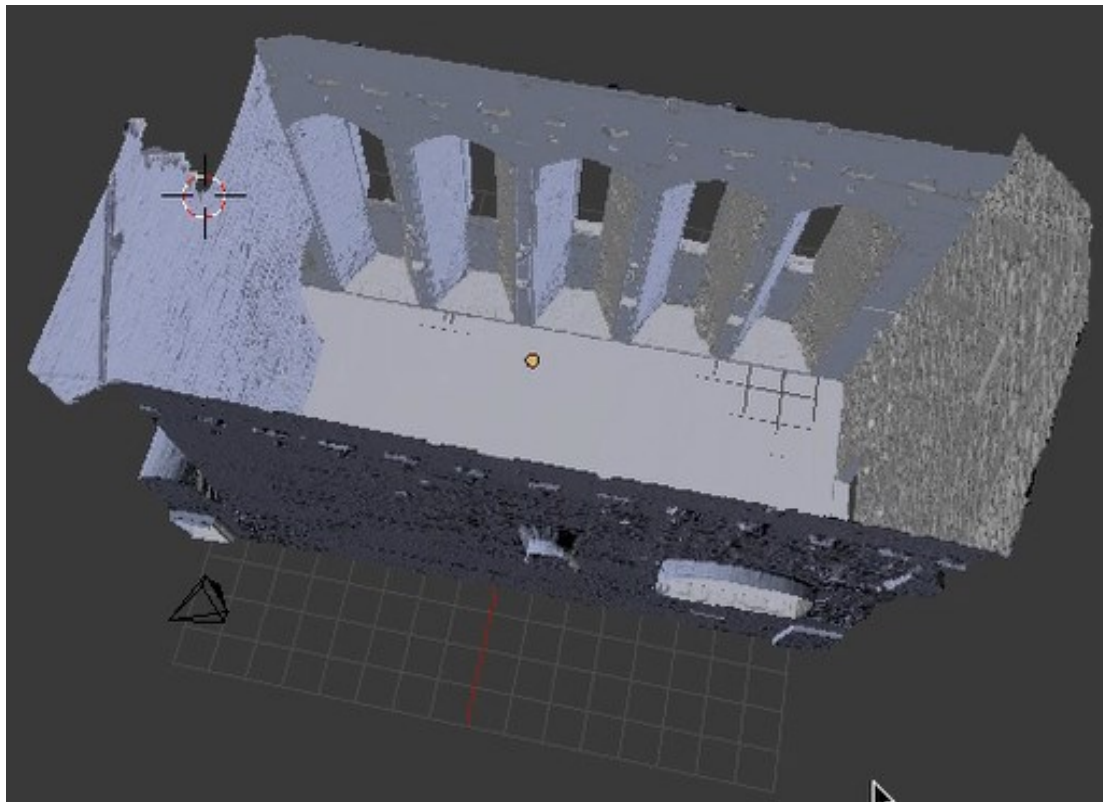


Image One: A highly detailed Lidar Scan of Linlithgow Palace Chapel

¹⁴ Lyn Wilson, Al Rawlinson, et al., '3d Documentation Of Global Historic Sites: The "Scottish Ten"; Project And Its Applications For Cultural Heritage', *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences* 38(5)/W16 (2011), 39-44.

¹⁵ Markus Schütz, Katharina Krösl, and Michael Wimmer. 'Real-Time Continuous Level of Detail Rendering of Point Clouds.' *Institute of Electrical and Electronics Engineers Conference on Virtual Reality and 3D User Interfaces (VR)*, 2019.

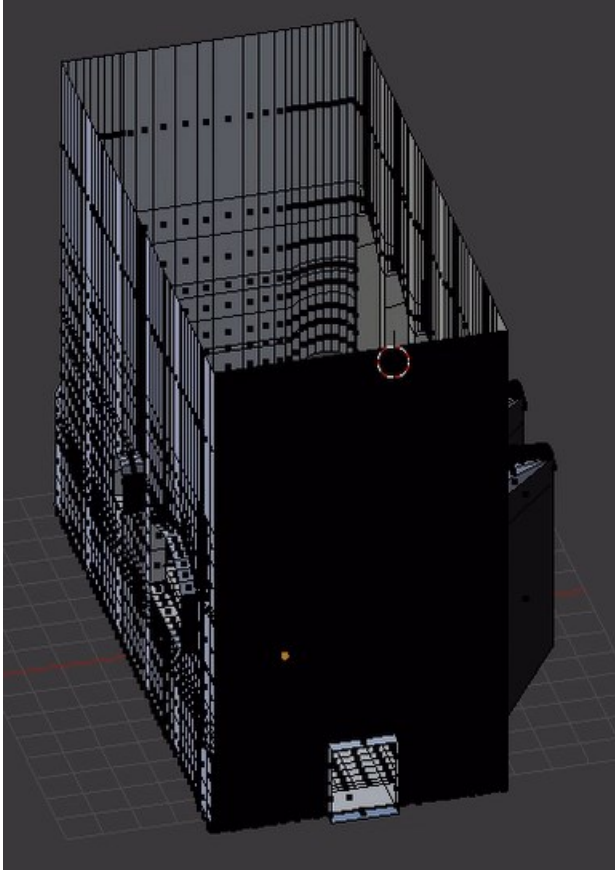


Image Two: The LIDAR scan following a reduction in polygon count

This gave us a detailed re-creation of the building in its current state - but it nonetheless gave little idea of what the building might have looked like in the past. We therefore used the measurements as a structural basis, and began to reconstruct the building around this skeleton.

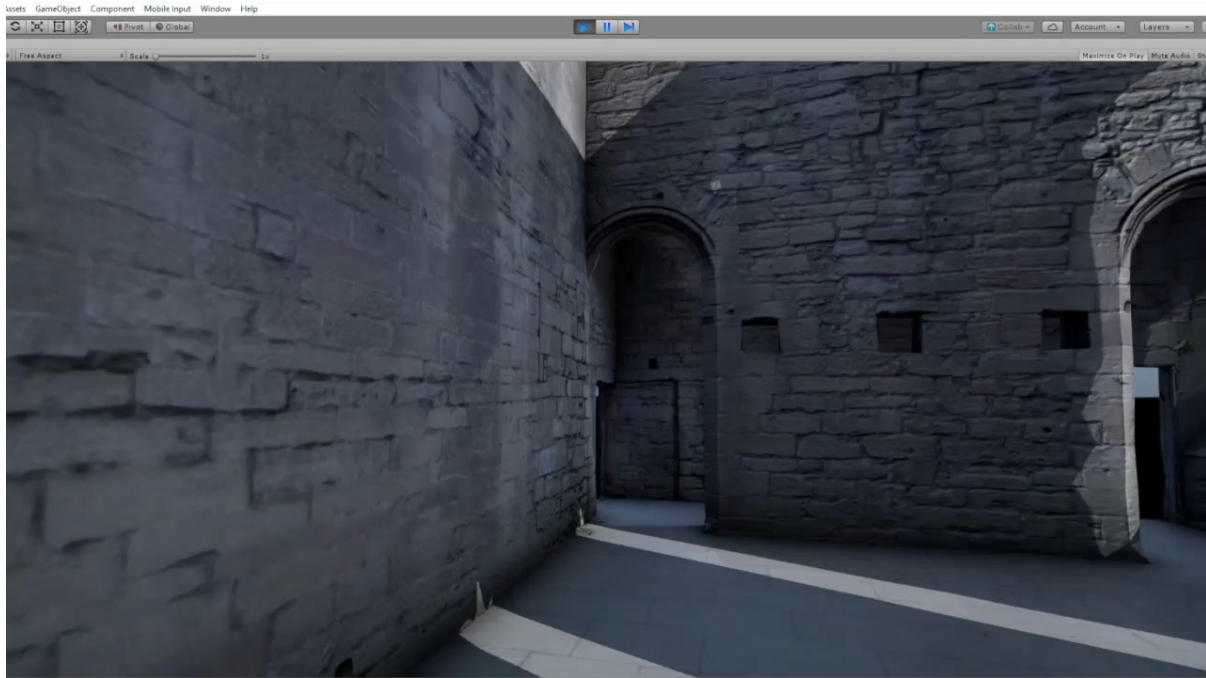


Image three: A digital reconstruction of the Chapel of Linlithgow Palace, as it stands today, constructed from LIDAR scanning with overlaid textures

Working with standing-building archaeologists, historians, and art historians, as well as the archival records, we were able to reconstruct the layers of building work on the chapel. According to Historic Environment Scotland's Archaeological Survey of the site,¹⁶ the two archways that occupy the east wall of the chapel show no sign of ever having had doorways, since there is no evidence of anything onto which these could have been affixed. It is therefore assumed that the area beyond these forms a part of the liturgical space, potentially functioning as an ambulatory allowing for a processional route behind the altar, such as that of the new Chapel Royal at Windsor, erected by Edward IV c.1477-83.¹⁷

Given the small width of the space, it is hard to see how it could have functioned for anything other than the smallest of processions; hence rather than leaving these archways entirely open, we chose to close them with drapes, on the assumption that limited size would have inhibited

¹⁶ *Linlithgow Palace: Archaeological Survey and Historical Research*, vol.1. Kirkdale Archaeology (2015), 188.

¹⁷ Timothy Tatton-Brown, 'The building of the new chapel: the first phase', in N. Saul and T. Tatton-Brown (eds.), *St George's Chapel, Windsor: History and Heritage*, 69-80. (Wimborne Minster: Dovecote Press, 2010).

any kind of regular ritual use.¹⁸ There are no specific mentions of fabric for Linlithgow palace; there are, however, notable mentions in the treasurer's accounts of large purchases of material that relate to the King's household, but which are not assigned to particular parts of the building. One possibly relevant record is the following: 'Item, for xij elne taffetj to be ane trevis to the King ; ilk elne xvj s. ; summa . . . ix lt. xij s.' 11 elne of material gives a total of 44 feet, easily sufficient for our purposes. The term 'trevis' is often used to describe a dividing curtain in a chapel, though it can also refer to more domestic uses, such as in bedrooms. After 1529, with the appointment of the Master of Works to the Crown of Scotland, we have rather more specific information surviving for the construction and refitting of Royal buildings through the surviving accounts for this office,¹⁹ but it is clear that before this date not all expenses related to these buildings survive in the Treasurer's Accounts.

The archway on the West wall, like those on the East, has no surviving evidence of attachments for doors. It is nonetheless unlikely that the chapel ante-room, into which it leads, would have constituted one unbroken space with the chapel. We therefore chose to cover this wall with a drape, similar to that on the East wall; the surviving stone rail at the top of the wall would offer the method of attachment for this.

There were clearly two different stages of roof building within the chapel. The first stage, relevant to our reconstruction, was slightly lower than the second. We have rather more archival material relating to the second layer of roof building, since this took place after the appointment of the Master of Works. In May 1535, there were payments for nineteen joists for the chapel, each 36 feet in length (the correct width of the chapel).²⁰ There are 13 joist sockets that survive in what we have identified as the second layer of roof building, providing for 6 joists for supporting the gallery/loft, which we believe to have been completed around this time. A month later, payment was made for birch scaffolding for the chapel ceiling, presumably

¹⁸ This same arrangement was independently assumed in Historic Environment Scotland's interpretational historical drawing.

¹⁹ Edited in Henry Paton (ed.), *Accounts of the Master of Works*, vol. 1, 1529-1615 (Edinburgh: H.M.S.O., 1957), and John Imrie and John Dunbar (eds.), *Accounts of the Master of Works*, vol. 2, 1616-1649 (Edinburgh: H.M.S.O., 1982).

²⁰ *Master of Works Accounts*, I, 123..

to allow for the installation of these joists.²¹ No payment records survive relating to the earlier roof, but its arrangement is obvious from the surviving joist sockets.

The ceiling of the second layer of roof construction was certainly painted. John Ross painted the 'lyning' of the chapel 'syloing' in 'fine assur' as well as twelve pendant knobs under the chapel loft.²² Whilst no records survive for the decoration of the first layer of work, we do not take this to be evidence of a lack of decoration since we also lack any payment records for the construction of this version of the roof in the first place.²³ We therefore followed a similar decoration scheme to that of the second layer of work.

As with the roof/ceiling, far more evidence survives of a second iteration of glazing in the windows. In the mid-1530s, the five windows had 268 ft² of clear glass and 29 ft² of painted images.²⁴ This works out to approximately 60 ft² of clear glass in each window with a 6 ft² panel of coloured glass. In contrast to the ceiling, there was no practical need to replace the glass in the 1530s; this must have been an aesthetic choice, so we decided to glaze the windows with predominantly clear glass, decorated simply with the Coat of Arms on James IV on each window (following a pattern found at Stirling Palace).

There are small surviving remnants of plaster on the walls in the chapel, so all walls in our virtual model have therefore been plastered. There is no indication of how the plaster may have been decorated, but we chose to apply *Trompe-l'œil* painted tiles, as seen in Stirling Palace from a similar date. The South wall has a number of niches that clearly once held statues of saints. There is, again, no explicit reference to these in the literature, so we chose saints who we believe to have been likely choices, given the context. These include St Andrew, the patron Saint of Scotland; St Michael, the dedicatee of Linlithgow Parish Church, which sits next door to the palace, and also the dedicatee of the chapel Royal in Stirling, Robert Carver's Mass *Dum sacrum mysterium*, and James IV's colossal warship 'The Great Michael' which was built at roughly the same date; St James, James IV's namesake; and St Margaret, that of his wife.

²¹ Ibid., 124.

²² Ibid., 128.

²³ This clearly did exist: the chapel was used extensively before 1535 and, as mentioned, joist sockets survive.

²⁴ *Accounts of the Master of Works I*, 128.

Some 500 fragments of clay floor tiles had been found during archaeological digs in the palace by 1996,²⁵ including one containing an intertwined I and M, which probably dates them from the years immediately following 1503 when James IV married Margaret Tudor,²⁶ making them appropriate for the flooring of the chapel, completed shortly thereafter. . The masons responsible for the 'paythment' of the chapel were part-paid in February 1507, with a further payment in April.²⁷ On James IV's visit to Linlithgow in August of the same year, the masons were paid 42 shillings 'in drinksilver',²⁸ a common practice of paying a gratuity that was to be spent on drink.

The positioning of choir stalls proved to be problematic. The archaeological survey suggested that they would have been placed along the north and south walls (as would be traditional), though there is absolutely no surviving physical evidence of this.²⁹ However, as also noted in the survey, this creates a problem of positioning due to the deep window bays which become entirely hidden by the choir stalls, blocking much of the light through the stained glass. Positioning these too close to the altar also produced logistical issues for access to the ambulatory, and for most positionings of singers around a lectern. No matter where these were placed, they left very little space between them due to the narrowness of the chapel.

The early chapel at Stirling Castle certainly did include wooden choir stalls with canopies, as these were used as the model for the stalls in Glasgow Cathedral in 1506.³⁰ We might therefore have expected that Linlithgow would also have had stalls since the personnel of the Chapel Royal served both. Nonetheless, Linlithgow Palace chapel was significantly smaller than the space at Stirling. Even the latter's earlier 15th-century chapel, closest in age to Linlithgow, still measured upwards of 9m x 29m. This makes the footprint of the building some 261m², versus only 120m² for Linlithgow. It is possible that James was attended by less than a full complement

²⁵ For a full account, see David Caldwell and John Lewis, 'Linlithgow Palace: An Excavation in the West Range and a Note on Finds from the Palace', *Proceedings of the Society of Antiquaries of Scotland*, 126 (1997), 823-869.

²⁶ See *ibid.*, 837, for an image.

²⁷ James Balfour Paul (ed.), *Compta Thesaurariorum Regum Scotorum: Accounts of the Lord High Treasurer of Scotland* vol. II (Edinburgh: H.M. General Register House, 1900), 297-8.

²⁸ James Balfour Paul (ed.), *Compta Thesaurariorum Regum Scotorum: Accounts of the Lord High Treasurer of Scotland* vol. III (Edinburgh: H.M. General Register House, 1901), 411.

²⁹ *Linlithgow Palace: Archaeological Survey and Historical Research*, vol.1. Kirkdale Archaeology (2015), 189.

³⁰ John Dunbar, *Scottish Royal Palaces*. (Glasgow: Tuckwell Press, 1999), 126.

of the Chapel Royal when in Linlithgow: Robert Lindsay of Pitscottie notes that half of the Chapel Royal would travel with the older James III.³¹ Certainly there is documentary evidence for the transporting of the ‘chapele geir, organis and eucharist’ to Linlithgow in 1512,³² suggesting a somewhat less permanent installation, at least until the later installation of an in-built organ.³³

One final problem which, combined with the above concerns, caused us to discard our choir stalls, was the positioning of seating for the royal couple. A later addition to the space was a wooden loft which sat above the West wall of the chapel.³⁴ This has been suggested possibly to have been an organ loft, or a box that allowed the royal family to watch proceedings. More recent archival research suggests that the first of these suggestions is less likely, since there is seemingly insufficient material in the 1513 accounts relating to the organ’s attachment to the wall for the loft to have been constructed - and there does not appear to have been a relocation of the organ at a later date. In either case, it is clear that there was nowhere separate to seat the monarchs at the date of our reconstruction. In the end, we followed the Historic Environment Scotland interpretative reconstruction and set seating for the royal couple on the North and South wall. The practical impact of these decisions on the experience of liturgy in the space is something that we are only beginning to explore through our VR model.

As should be clear from the above discussion, some aspects of how the chapel was arranged are entirely obvious from the surviving archaeological and archival record; others are the product of what we hope is intelligent guesswork, building upon the firm points of information that we do have. Many of the aspects to which we have had to apply a level of interpretation

³¹ Aeneas James George Mackay (ed.), *The Historie and Cronicles of Scotland: From the Slauchter of King James the First To the Ane thousande fyve hundreith thrie scoir fyftein zeir, written and collected by Robert Lindesay of Pitscottie*, (Edinburgh and London: William Blackwood and Sons, 1899), I, 200

³² James Balfour Paul (ed.), *Compta Thesaurariorum Regum Scotorum: Accounts of the Lord High Treasurer of Scotland* vol. IV (Edinburgh: H.M. General Register House, 1902), 347. The transport was organised by David Trail, Sacristan of the Chapel Royal.

³³ The permanent organ was installed in April 1513. A French organ builder, named Gilyem, was paid 10 ‘licht Franche crounis’ for its construction. A detailed description of its method of attachment to the wall of the chapel, and the associated costs, may be found in *Compta Thesaurariorum Regum Scotorum*, vol IV, 523.

³⁴ The positioning of the surviving joists and the fact that the loft must have partially obscured one of the original windows in a fairly inelegant manner, combined with the above-mentioned archival evidence for the purchase of wood, makes it most likely that this was indeed a later addition.

would have had little perceptible relevance for the acoustic features of the space, though some, such as the inclusion and placement of choir stalls, would obviously have had greater impact. One great advantage of virtual over physical reconstruction is that it is possible to re-arrange the physical space with relative ease and to use this facility to explore aspects of liturgical re-enactment.

Acoustic Reconstruction:

Once we had a sense of how the interior of the building might once have looked, we were able to begin our acoustic reconstruction. This relied on a detailed understanding of the acoustic properties of the materials used to construct the building. All materials will reflect and absorb sound by different amounts at different frequencies; those with rough surfaces will also scatter the reflected sound more than those with a smooth surface.³⁵ We therefore tagged all surfaces in our reconstruction with a number of coefficients relating to absorbency over the range of audible frequencies, and a scatter coefficient so that we were able to model how sounds would have interacted with them.

Once all the surfaces in the model had the required acoustic information, we were able to derive an impulse response for the room. This is a measure of all the reflections at all audible frequencies between the sound source and receiver (see images four and five). It can be plotted graphically, as shown below, but can also be saved as a .wav file that can be loaded into a convolution reverb plugin, allowing for the application of this room-sound to any sound source. In our reconstruction, a process known as ray-tracing was employed, whereby reflections from all the surfaces and objects in the space were simulated to produce this impulse response. Once this was obtained, we were able to imprint the acoustic characteristics of the modelled space on our recorded music.

³⁵ See, for instance, Jens Holger Rindel. 'The use of computer modelling in room acoustics.' *Journal of vibroengineering* 3.4 (2000), 219-224.

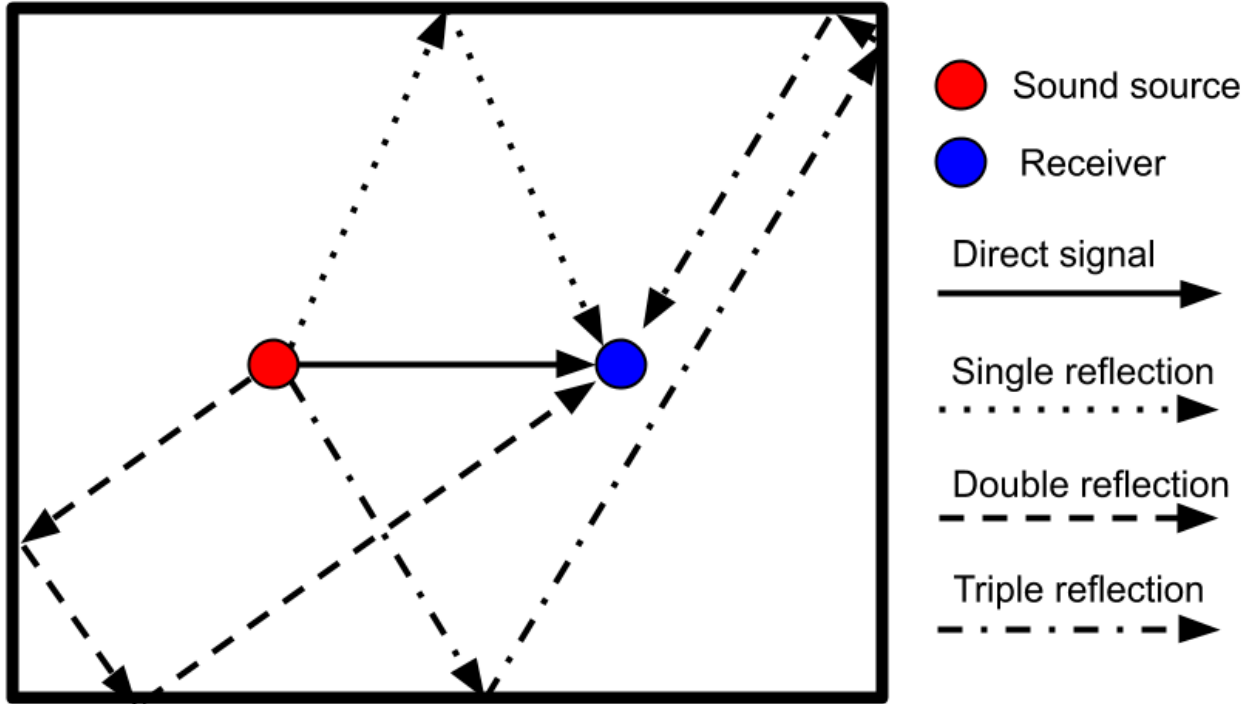


Image Four: A graphical representation of how sound interacts with a space in its travel from sound source to receiver

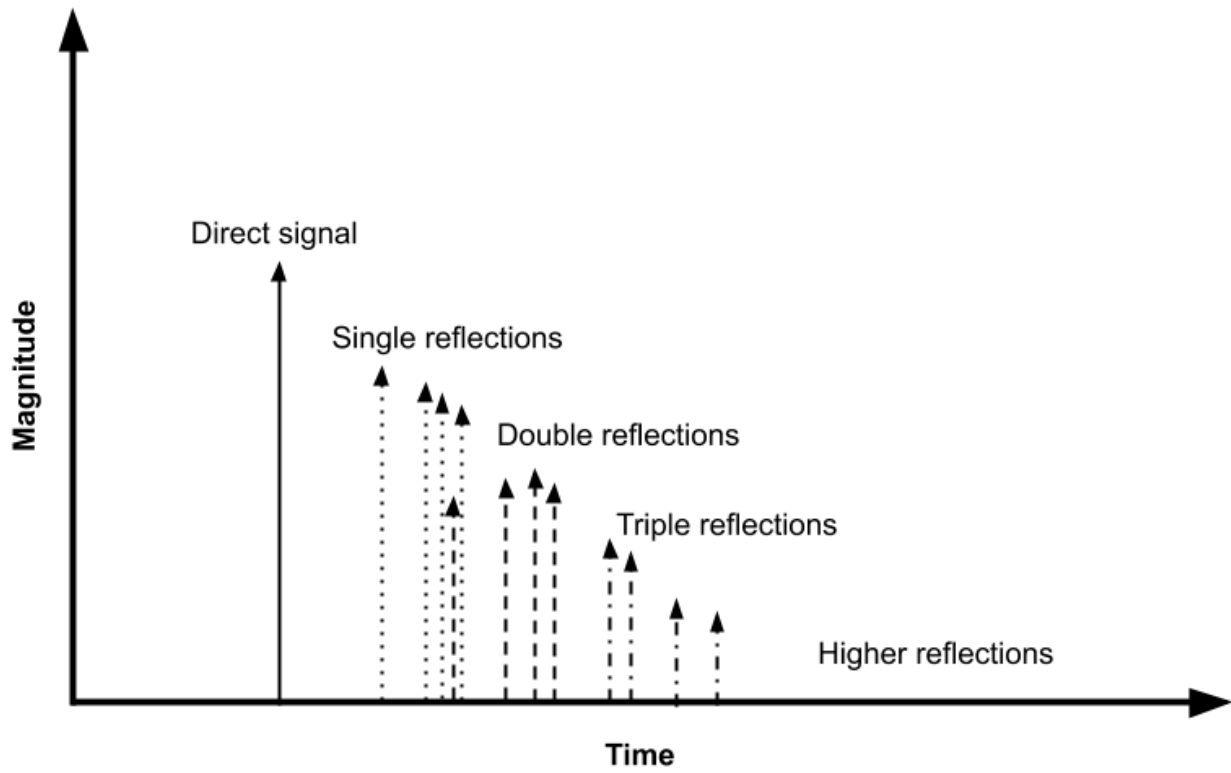


Image Five: The reflections from image four mapped onto a graph (the traditional visual presentation of an impulse response)

For an initial pilot project, we produced an interactive Virtual Reality application that allowed the user to move around in the space freely whilst appropriate music is performed. A version of this application – optimised for use in a heritage setting — can be experienced through a number of VR headsets on site at Linlithgow Palace, Scotland. We were keen to have experimental data that would allow us to judge the efficacy of our acoustic reconstructions, so we commenced scientific testing of the other VR reconstruction produced in the initial project, that of St Cecilia’s Hall, Edinburgh, the oldest purpose-built concert hall in Scotland.³⁶ By comparing an impulse response derived from acoustic ray-tracing in our reconstruction of the hall in the present with an impulse response derived from a Sine sweep in the hall (with both the sound source and the receiver identically positioned),³⁷ we were able to judge how effective our reconstruction process had been.³⁸

A comparison of Odeon, the industry standard software for acoustic modelling, with Steam Audio and Google Resonance, was also run. Odeon is the most accurate, but is computationally very intensive and therefore unsuitable for real-time acoustic rendering with moving sound sources or listeners, such as was intended for the VR experience at Linlithgow Palace. Steam Audio and Google Resonance, as game-engine applications, are optimised for this usage, even at the expense of some accuracy. Both Odeon and Steam Audio produced similar reverberation times to the real-world room impulse response generated via a Sine sweep.³⁹ Google

³⁶ A VR installation of this reconstruction, which will compare the hall in its present configuration against that of 1759, will be publically available at the concert hall.

³⁷ A Sine sweep involves using a tone derived from a Sine wave which moves across all audible frequencies, in this case starting at low pitch and ending at high pitch.

³⁸ A similar process could have been undertaken with the Linlithgow model. However, this was complicated by Linlithgow Palace’s status as a tourist site and the fact that it has no roof or windows. This made obtaining sufficiently clean recordings exceptionally difficult. The presence of a colony of rare bats in the ruin was also problematic for the use of high frequencies within the Sine sweep.

³⁹ The slight deviations in reverberation times between the real-world impulse response and those produced by Odeon and Steam audio can be accounted to the differences between industry-standard absorption coefficients and actual ones, the presence of two investigators in the space during the real-world experiment, and the characteristics of the microphones and speakers

Resonance, which relied unduly on pre-set conditions, was far less effective.⁴⁰ Steam was chosen as the audio plugin of choice for use in a live-simulated VR context. The CD project, as will be discussed below, had no need for audio to be responsive to movement from the listener, or to evaluate acoustics in real time, and could therefore make use of Odeon, for greater accuracy.

Recording Process:

In order to produce as clean a reconstruction of the acoustics as possible, it was important to record the music in a setting which had close to no natural acoustic. We therefore recorded within an anechoic chamber at the University of York, the kind of space more typically used by engineers and physicists to test materials (see image six). This allowed us to produce a performance as though it were taking place in our reconstructed space, without also overlaying the acoustic of a studio or other venue. An anechoic chamber does not make for the most natural performance space. The environment is claustrophobic, hot, often—as in this case—with springy floors, and it offers very little in the way of feedback to the performer. What little feedback the performer does receive is, of course, related to the chamber and not the intended eventual reconstructed acoustic. It is therefore also important to ensure that performance decisions reflect the intended reconstructed acoustic, rather than the acoustic of the chamber. Our entire production process was therefore significantly changed for this recording.

As director of the Binchois Consort, Andrew Kirkman has often commented on how frequently he has implored the singers, when sound-checking in one of the many cavernous churches where they have performed, to make more of the consonants, since past the closest members of the audience these become all but inaudible with anything approaching standard enunciation. Similarly frequent is the experience, after the sound check in a recording session, of having the engineer push the mics closer to the throats producing the sounds. Inevitably the

⁴⁰ For a full discussion of this experiment and its results, see Rod Selfridge, James Cook, Kenneth B. McAlpine, and Michael Newton, 'Creating Historic Spaces in Virtual Reality Using Off-The-Shelf Audio Plugins', *Proceedings of the Audio Engineering Society Conference*, 2019. Available at <https://www.aes.org/e-lib/>

agreed positioning has always come down to a compromise, not least because—bluntly—close-micing can be terrifying for the singers and hence impede musicianship.⁴¹

The experience of recording in an anechoic chamber was therefore one that we all approached with a certain temerity: as director, engineer, producer, researcher, and singer. In truth it was less daunting for some of us, who had tried it the year before in Edinburgh as part of the same project, but surely no one would claim that such an experience is ‘enjoyable’; and while we all approached it in good faith, it is fair to say that singers (and even directors) who attempt to record in such a space need to be prepared for an experience which is quite distinct from, and a fair degree more challenging than, that of recording in any other space. A degree of trust between the performers and the research team was certainly necessary, and so too was a high degree of patience and perseverance for all involved.

⁴¹ For a discussion of the impact of mic position on early music performance, see Kirsten Yri, ‘Remaking the Past: Feminist Spirituality in Anonymous 4 and Sequentia’s Vox Feminae’. *Women and Music: A Journal of Gender and Culture* 12, no. 1 (2008): 1–21. She notes how the close micing technique applied on recordings by Anonymous 4, in comparison to the more distanced placement on recordings by Vox Feminae, produces a ‘subjective “I”’ voice, in comparison to an ‘objective “other”’ voice. Both recordings, nonetheless, are markedly more reverberant than the recording discussed here, with artificial reverb added to Anonymous 4’s recording, such that the music appears to ‘radiate out’ from the close mic’d performer. Our mic placement sits somewhere between these two extremes, intimate – due to the nature of the reconstructed space - but still objective.



Image Six: The Binchois Consort with Andrew Kirkman in rehearsal in the Anechoic chamber, York University

Once the heavily padded door thuds shut there is essentially no reverberation at all, and the surrounding—of spiked foam (on five sides) and sprung floor above spiked foam (on the other)—can be daunting, a setting, to paraphrase our engineer Phil Hobbs, of having ‘a bunch of large blokes standing on a trampoline in a cupboard’.⁴² The experience is certainly claustrophobic, but more than that it serves to strip the performer of any illusions, making starkly clear the slightest of infelicity of intonation – not only skill, but supreme confidence in that skill, and those of your fellow performers, was required.

When the singing stops, there is nothing to hear except the sound of one’s own breathing and the blood pumping in one’s ears. How does one approach singing in such an environment? The initial urge, at least for some, was subconsciously to push the tempo in a (vain) effort to ‘get something back’. That phase over, however, it was surprising how quickly and how strongly the singers’ attention shifted onto each other, giving a much more intense focus on sound

⁴² For a short film showing the process of recording in the anechoic chamber, see <https://blogs.ed.ac.uk/spsm/>

production than one usually experiences. Absence of any acoustical distraction, or perhaps scope for evasion, forces a focus on intonation and blend that, while intimidating, is ultimately very productive: matching of vowels, a consideration which usually absorbs a great deal of time and effort, especially but not exclusively because of our attempts at localised, period pronunciation, becomes so obviously integrated with issues of pitching that it is impossible to ignore. As a result, while there is an inevitable sense of 'walking on eggshells' since every error is instantly, vividly present, there is also a degree of listening that is unusually concentrated. Progress, while inevitably quite slow, assumes its own pace as everyone acclimatises to the new situation. Yet blend does not equate to bland: what one is left with is the irreducibly distinctive timbre of each individual voice, chiselling out its line with due deference to the tuning and uniformity of the whole, a pertinent reflection, one might venture to suggest, of the kind of interplay that is inherent to the style of the music.

The elephant in the room in such a scenario is obviously how one arrives at performance decisions, such as tempo, phrasing, diction, and blend, for an environment that, to all intents and purposes, does not really exist. We experimented with many approaches, initially recording with headphones that fed back a real-time rendering of the singers with the acoustic overlaid. The singers found this somewhat distracting so, after experimenting with one ear off and one ear on; with only the director using headphones; and with the director with one ear off and one ear on, we eventually continued with no artificially supplied acoustic. Instead, performance decisions were discussed in advance, short sections were recorded and then reviewed in the control room with the overlaid acoustic. By regularly listening back to the recordings with the overlaid acoustic between takes we were able to maintain a musically appropriate approach to the reconstructed acoustic.

Overall, we were keen that this project be more than an exercise in sonic reproduction: we sought to produce something distinctive and musical in its own right, with due deference to historically-informed performance practice. Finding a workable balance between the scientifically recoverable and the artistic, which often had different priorities, was very much at the heart of this project.

For others seeking to approach work of this kind, there are a number of aspects which should be taken into account. Firstly, more time is certainly required for the recording, taking into account time taken to acclimatise to the chamber; more frequent, shorter takes; the need for more regular breaks from the oppressive environment; and the necessity to check performance decisions against the artificial acoustic. Secondly, performers require a high degree of self-confidence both in their intonation and their rhythm. Thirdly, there has to be real buy-in from the performers in the overall project, and an understanding that the difficulties are worth it. Nonetheless, we would consider it an extremely worthwhile exercise, not only for the manner in which it supports scientific accuracy, but also for the unusual level of attention-to-detail it enabled in the recording process.

Further Implications of the Project

To close the current account and simultaneously to open it out to future possibilities, we wish to turn again to the putative environment with which our sonic experiment sought to interact. The reconstruction of the chapel of Linlithgow Palace is narrow (8m) and high (11m), but comparatively long (15m), with a coffered ceiling of wood, and significant soft furnishing, especially towards either end of the chapel. This creates an environment with little scope for reverberation: the sound has little distance to travel either side of the choir, and where it would have more room for reverberation, reflecting between the East and West walls, it is largely absorbed (particularly at higher frequencies) by the hangings. It is towards these, moreover, that the direct sound of the singers is first aimed.⁴³ The roof too, in its use of coffering, tends to a relatively uniform sound, while wood by its nature is more absorbent (especially of lower frequencies) than stone. Nonetheless the fact that the building is tall and long offers some support, and the tiled floor is relatively reflective. The acoustic effect therefore stands somewhere between that of the chancel in a large cathedral and that of a side chapel, the latter the typical original location of privately endowed polyphony of the fifteenth and sixteenth

⁴³ On this point see the discussion of the effect of wall hangings in Alicia Alonso and Francesco Martellotta, 'Room Acoustic Modeling of Textile Materials Hung Freely in Space: from the Reverberation Chamber to Ancient Churches', *Journal of Building Performance Simulation*, 9 (2016) 469-86. Key to our discussion here is the finding that absorbency of sound by fabric is directly related to its distance from walls, with fabric being considerably more absorbent when freely hanging than when adjacent to a solid surface.

centuries, and hence of much of the grander repertory of the era. It is, nonetheless, a world away from the kind of acoustic that would normally be used for a commercial CD of this repertoire, especially those produced for larger record producers, and using similar forces to those found in The Binchois Consort.

The larger point, acoustically speaking, that our experiment addresses is that many of the most ornate and highly valued pieces of music from the era—Mass settings, Marian antiphons and so on—were originally fashioned for performance in enclosed spaces, frequently with wall-mounted hangings and flooring covered with strewn grasses, of very limited square footage and commonly with roofs considerably lower than those of adjoining naves; spaces, in other words, that were acoustically much less resonant than those in which we are accustomed to experiencing the same music today. Leaving aside the question of who, in the fifteenth century, was doing that experiencing, we might add to this the absorbent effect on that acoustic of proximate human bodies occupying considerably more space relatively speaking than if positioned in, say, a cathedral nave.

Vaulted roofing is an interesting complication to the overall picture here, since it tends both to increase reflection time and decrease clarity due to the interaction of reflections from separate vaults. Some certainly valued the effect of vaulting on music, as seen in the comments, in 1535, from Francesco Giorgi on the building of San Francisco della Vigna in Venice, which state: ‘I recommend that all chapels and the choir should be vaulted, because the words or the songs of the clerics [are] better reflected from a vault than from a wooden ceiling’.⁴⁴ Presumably what was esteemed here was the amplification and relative spread of the sound throughout the space, rather than its tendency to decrease clarity. Giorgi clearly was aware of the negative aspects of vaulting too, since he also noted that ‘for the nave of the church, where there will be sermons, I recommend a flat ceiling (so that the voice of the preacher is not lost in or reflected from the vaults). I wish for a coffered ceiling with as many squares as possible... and I

⁴⁴ Baumann, ‘Musical Acoustics’, 208, and Lewcock, et al, ‘Acoustics’.

recommend these coffers because, among other things, one can preach well beneath them. The experts know this and experience will justify it'.⁴⁵ Vaulting within larger buildings (a cathedral nave, for instance) tends to have a lesser impact on the clarity of the sound, since acoustics of spaces of very large volume seldom receive enough energy in them to excite the room. It seems clear that architects and musicians of the period were quite capable of negotiating both acoustically deadening effects and their opposites in order to produce the kinds of sounds for which they were looking. In essence, small side chapel spaces, with their close walls and soft furnishings, are offered a little additional support by vaulting, whilst the resonance of larger spaces could be dampened by coffered ceilings (as was apparently the case at Linlithgow).

Our experiments are obviously far from exhaustive. There is certainly more to be done exploring the practicalities of liturgical re-enactment in virtually reconstructed spaces, and especially in side chapels. Nonetheless, our work has yielded important insights. Perhaps the most salient of these is that our reconstructed acoustic is a world away from that in which we, and indeed most professional groups with similar forces and working on similar repertoire, would typically have recorded a CD. The acoustic allows for a compellingly close focus on the interweaving of voices and the fine detail of the counterpoint, and we feel that the absence of the extra reverberation usually experienced in this repertory is more than compensated for by the up-close engagement with musical precision that it affords.

Equally striking, however, is the effect of rehearsing and recording in an anechoic space: the sharply enhanced listening resulted in a crispness of consonants, uniformity of vowel sounds and speed of responsiveness both to text and musical events that is unexpectedly vivid and exhilarating: to its performers and director a level of engagement and musical 'honesty' that could truly be described as revelatory. Though inevitably more labour-intensive, therefore, the results offer a level of musical immediacy unmatched by our prior recordings, produced as they were in more forgiving surroundings; and while it is well to beware of possible hubris in drawing historical inferences, we would venture to suggest that such uniformity might offer at

⁴⁵ Baumann, 'Musical Acoustics', 208-9; Lewcock, et al, 'Acoustics'.

least some insight into the experience of our medieval musical forebears, accustomed, as so many of them were, to singing the same small repertoire day after day, year after year, in the same company and in the same close surroundings.

One must of course allow that a more distanced, 'ethereal' experience of late medieval music may be some listeners' preference. How could it be otherwise: they have grown to love the music in the context of the spacious sound more customarily experienced in connection with this repertoire, both in recordings and, crucially, in concert venues.

. Whatever may be determined regarding original locations of performance, the reality is that concerts of this music are typically mounted not in intimate chapels, but in cavernous naves spaces not only more in keeping with familiar modern experience but also capable of accommodating the sizes of audiences that permit their financial viability. In the UK, as elsewhere in Northern Europe, moreover, successive generations of confessional reform, alongside sacred architectural and interior design movements, have left such spaces devoid of their original screens and soft furnishings, leaving them still more open and reverberant than would have been the case at the time of the music's composition.. The reality of concert and festival promotion means that this situation is unlikely to change; but as musical experimentation with virtual reality becomes increasingly the norm we can surely look forward to further experiments with ambient sound in spaces more attuned to those of the late Middle Ages, with attendant gains in aural vividness and, perhaps, historical insight.⁴⁶

⁴⁶ The CD 'Hearing Historic Scotland: Inside the Pleasure Palace of James IV' is available from Hyperion Records (https://www.hyperion-records.co.uk/dc.asp?dc=D_CDA68333).