04_01_Spatiosonic Dialogues: Exploring Architecture's Role in Music Composition and Performance

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Abstract

This chapter reflects on a project[1] made as part of a larger body of practice-based architectural research which examines conceptual and practical relationships between the spatial and sonic practices of making space and making sound, through the medium of site-responsive composition. The project compares two performance spaces with extremely contrasting acoustic characteristics, as a means of examining these relationships in detail. Historically, architecture and music have enjoyed a productive symbiosis, as evidenced in the spatially diverse compositions of Adrian Willaert (c. 1490) and more recently in the collaborations such as the one between composer Luigi Nono and architect Renzo Piano for the opera Prometeo (1984). To build upon such work, this chapter discusses the composition and performance of a duet, created by the author. This duet was performed at the acoustically dry location of an anechoic chamber at University College London and at the acoustically reflective space of the Basílica de la Sagrada Família (BSF) in 2017. The Sagrada Familia's interior has an average reverberation time of approximately 12 seconds.[2] This is problematic for achieving speech intelligibility in the delivery of sermons. Many engineers and designers have attempted to fix this problem with proposals to retrofit acoustic absorbers. However, the composition discussed in this paper takes advantage of this unique condition, by locating musicians at different points around the space and using the building's reverberation to blend their soloistic parts into a series of undulating harmonic events. By contrast, the anechoic chamber offers a completely dry acoustic condition. This project examines the role of architecture in musical performance. It comes at a time when concert hall design is becoming more standardised due to design trends that favour acoustic certainty for clients and occupants. In this research, Architecture is examined as an active component of music composition and performance as opposed to a mere container for such events.

Introduction

This chapter explores a project composed for and performed in two extremely different acoustic and spatial environments, titled 'Construction 002: Tracing / Occupying' (C002). The aim of this project is to question the role of architecture in the performance and composition of music, following a rich history of symbiosis. The project adopts a multidisciplinary approach, using tools, methods, and vocabularies commonly used in the design of spaces for music, as compositional tools. Such an approach is referred to as 'spatiosonic'[3] throughout this chapter. It also questions architecture's role in musical performance, particularly at a time when concert hall designs are becoming standardized due to trends favouring acoustic certainty for clients and occupants. In this context, architecture is examined not merely as a container for events, but as an active component in music composition and performance.

The motivation for this research comes from a fascination with a quote from physicist Hope Bagenall in which he recalls: 'A legend exists that a Mass by Fairfax-a mediaeval organist of St. Albans-was composed with a fourth part supplied by the church. Even if this was no more than a legend it shows that the building was recognised as an instrument'[4] Whether real or fictional, Bagenall's account of this spatial, resonant phenomenon sparked the idea of music being composed and performed WITH a building, rather than just happening TO a building. This research

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[1] This project was generously funded by the Australian Research Council.
[2] Zhao et al., 'A Preliminary Investigation on the Sound Field Properties in the Sagrada Familia Basilica'. P5.
[3] The word 'spatiosonic' is a self-coined portmanteau which (though not currently recognised by any dictionary) discusses a plethora of resonances between spatial and sonic practices, without explicitly disclosing the nature of that resonance. This enables an elastic usage, in relation to either conceptual or practical resonances.
[4] Bagenal, 'Influence of Buildings on Musical Tone'. P443.

aims to explore the practical and conceptual resonances between architecture and music as a means of identifying creative opportunities and moving away from the problem/solution-based approach that currently dominates these fields.

C002 was initially performed in an anechoic chamber at University College London, where the room's acoustic response was completely dry. By contrast, it was also performed in the highly reverberant space of the Basílica de la Sagrada Família (BSF). In quantifiable terms, the vast interior of the BSF has an average reverberation time of almost 9.1 seconds and an early decay time of 11.9 seconds.[5] This is highly problematic for achieving speech intelligibility in the delivery of spoken-word sermons. Many engineers and designers have attempted to fix such a problem by proposing the retrofitting of acoustically absorbent surfaces. However, C002 takes full advantage of this unique condition, by locating musicians in spatially diverse positions around the space, whilst also employing the building's high levels of reverberation to blend their soloistic parts into a series of tonally undulating and spatially immersive harmonic events. While acoustic response is not the only crucial factor in the creation of spatiosonic works, it significantly influences the aesthetic of a musical performance, especially if deliberately harnessed. Crucially, this work not only capitalises on the existing conditions presented by a performance space but also uncovers less visually apparent obvious architectural features, such as materiality and capacity for spatialisation. In doing so, it challenges the role of architecture in shaping musical experiences. Additionally, it aims to gain insights beyond what is immediately observable or quantifiable.

Context

Architectural space has historically influenced music, as seen in the 'spatialised choirs' of Dutch renaissance composer Adrian Willaert, and in the spatialised compositions of 20th Century American composer Henry Brant. Both of these examples explore how aspects of physical space (particularly the parameters of distance and direction), can be as compositionally active as the explicitly musical elements of pitch, rhythm and timbre.[6] Conversely, architects and engineers have long recognised the desires of music and sound in space. Many of us are familiar with Vitruvian 'echea', or pots embedded in walls, used to enhance the acoustics of theatres and performance spaces.[7] More recently, collaborations between architects and composers, such as the project 'Prometeo' by composer Luigi Nono and architect Renzo Piano, have seen compositions and buildings conceived in tandem.[8] Despite these prominent examples, only a small handful of sonic and spatial practitioners have dedicated their research and practice to the rigorous exploration of creative, interactive parallels between the acts of making space and making sound in their work. This is perhaps surprising, given that architecture, acoustical engineering, music composition, and performance all offer ways to develop interactions between sound and space -- whether these interactions are explicitly calculated in advance or emerge from empirical and intuitive exploration and experimentation. Whilst the nature of these interactions are potentially rich and varied, current practice relies on highly reductive abstractions and representations, in order to anticipate, record and recall both architectural and compositional works. The trend of formalising and quantifying these relationships seemingly began when physicist Wallace Clement Sabine developed a method for predicting the time it takes for sound to decay in a space (based on room volume, surface area and absorption coefficient of materials which constitute the room).[9] Although predicting reverberation time is useful in building design as it offers an easily quantifiable description of (otherwise invisible) acoustic phenomena, it only discusses a very limited set of interactions between sound and space. As such, this approach overlooks more poetic dimensions, leaving plenty of unexplored potential in the intersection of spatial and sonic practices. This is not a new observation - it's a frustration shared by other practitioners and researchers. Architecture is rarely interrogated as anything beyond a mere container for music. The project explored in this chapter attempts to address this by questioning if architecture can itself offer compositional content.

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[5] Zhao et al., 'A Preliminary Investigation on the Sound Field Properties in the Sagrada Familia Basilica'. P5.
[6] Brant once stated that space is the 4th dimension of music, alongside these 3 listed elements: Brant, 'Spatial Music Progress Report'. P22.
[7] Vitruvius, 'Book V'.
[8] RPBW Architects, 'Prometeo Musical Space'.
[9] Sabine, 'Melody and the Origin of the Musical Scale'.

Acoustic response as a compositional parameter

The composition that forms the focus of this chapter, is part of a larger series of site-responsive compositions which examine a series of practical and conceptual resonances between architecture and music. C002 explores both the spatialisation of performers and the acoustic response of the performance space as deliberate compositional parameters. The lengthy reverberation times in the BSF have caused significant issues with speech intelligibility, particularly during sermons.[10] Teams of engineers and designers have suggested remedying this issue by retrofitting the interior with absorbent acoustic treatments. However, from a music composition perspective, this extreme acoustic environment presents a unique creative opportunity for a highly site-specific and acoustically-aware musical project.

Music composition often serves as a medium for expressing ideas. However, in the case of C002, it poses a question: 'How might architecture offer conceptual and phenomenological content for music composition?'. To explore this question in some depth, we can evaluate the same composition in two contrasting environments, focusing particularly on the acoustic phenomenon of reverberation, which is perhaps the most intuitively understood component of acoustic behaviours discussed in both architectural and musical contexts.

The notion of 'extreme' – derived from the Latin *extrēmus*, meaning 'situated at the end'[11] – is defined here as a relational condition, necessary for comparing two vastly different architectural conditions. The anechoic chamber and the BSF differ not only in their reverberant behaviour, but also in their capacity to spatialise sound sources (in this case, the performers). In the BSF, performers can be positioned at much greater distances than in a typical stage setting or the anechoic chamber (up to 20 meters vertically and 60 meters horizontally). This capacity enables the exploration of relationships between a performer's position (relative to each other and to the listener, or microphone) and the acoustic response of the space. Crucially, it provides insight into the role of reverberation and performer spatialisation in shaping and defining musical logics.

C002, a duet for violin and cello, exemplifies an experimental approach that refrains from explicitly defining the parameters of the acoustic condition within the BSF through quantitative analysis, as these definitions have already been established elsewhere.[12] Instead, its aim is to explore the atmospheric and poetic potentials within this acoustic environment. Architecture, being a largely visually focused profession, often neglects phenomena that can't be quantified or visually represented. Through music composition and performance, this project seeks to articulate spatial concepts and reveal architectural character on the terms of sonic media. This approach, referred to as 'spatiosonic practice' in the wider context of this research, could serve to broaden architectural discourse and suggest methods for furthering such an interdisciplinary practice. The development of spatiosonic practice relies not only on the performance of projects but also on the methods and tools used in their composition. Given this, it is worth noting that C002 was created using methods and tools typically used by architects and engineers to design spaces for music, thereby forming direct practical bridges between sonic and spatial practices. Computer programmes such as Pachyderm for Rhino,[13] EAR Acoustic for Blender[14] and CATT acoustic[15] were used to rehearse musical ideas. Specifically, these tools were used to predict the effects of varying performer positions and to understand how this spatialisation interacts with the building's acoustic response.

Architecture as a performer

When designing buildings, architects often discuss 'performance' in terms of specific attributes like thermal efficiency and fire safety. However, we rarely describe buildings as 'performers'. This project explores the notion that architecture, when activated by music, is a dynamic entity capable of embodying and expressing spatially dependent musical parameters. In essence, it challenges the traditional boundaries between architecture and performance,

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[10] Zhao et al., 'A Preliminary Investigation on the Sound Field Properties in the Sagrada Familia Basilica'.

[11] Dictionary, 'Extreme, Adj'.

[12] Zhao et al., 'A Preliminary Investigation on the Sound Field Properties in the Sagrada Familia Basilica'. P5.

[13] Open Research in Acoustical Science and Education, *Pachyderm Acoustic*.

[14] Krijnen, *EAR: Evaluation of Acoustics Using Ray-Tracing*.

[15] Dalenbäck, *CATT Acoustic*.

envisioning buildings not just as static structures but as active participants in the artistic realm of music composition and performance. This work then elevates the role of architecture beyond just being a container for sound. It suggests that architecture can provide compositional content, equal to traditional musical elements like pitch, time, and timbre. This idea derives from Brant's approach, which viewed space as the fourth element of music.[16] This in turn prompts the question: if architecture is a crucial part of a composition, does a change in performance location, especially when transitioning between environments as architecturally distinct as the anechoic chamber and the BSF, result in a variation of the musical piece, comparable to the alteration of other fundamental musical characteristics? This issue inevitably raises significant and subjective questions about the nature of 'the piece'. This is especially relevant in the era of AI-generated music, where content is typically based on libraries of existing examples and outcomes may closely resemble the original set of examples. There are many varying theories on what makes musical ideas portable. While a detailed discussion of 'work identity' is beyond the scope of this chapter, it is worth acknowledging the common practical notion that performances of musical compositions always contain deviations from the score. These deviations can be errors, embellishments, or omissions, but they don't necessarily change the piece altogether. According to philosopher Nelson Goodman, the score (and in the case of C002, also the drawing) clarifies compositional intent, which is crucial for interpreting and performing a work, thereby forming its identity.[17] Goodman's theory, surmises that 'a performance is a performance of a work only if it corresponds precisely to those elements of a score that are capable of precise definition'.[18] While this theory has been critiqued for its lack of adaptability to real-world scenarios,[19] the principle of the identity of the piece as being held in the documents that facilitate its performance can be usefully applied to the questions underlying this research, provided the key variables, including the architecture, are acknowledged and articulated in some way. From an aesthetic perspective, the music played in the anechoic chamber differs significantly from that played in the BSF. Despite using the same scores, the duration and presentation of musical content vary noticeably. The performance in the anechoic chamber has a distinctly melodic sound, while the BFS performances appear more drone-like, steering our attention towards harmonic over melodic concepts. This highlights the role of architecture as being implicit in the performance of compositional intent, where differences in performance space could be more carefully considered at the point of composition. It subsequently prompts the designers of buildings for music to consider 'what does music want'?

Along with the score and drawings for C002, the project's title significantly contributes to the understanding of the work. The full title, 'Construction 002: Tracing / Occupying' (C002) serves multiple purposes. It not only situates the work within a sequence of other spatiosonic 'constructions',[20] but also expresses the intention for the music to expose (or trace) the otherwise hidden sonic potential of architecture as a musical performer. Moreover, it outlines the compositional processes. The geometric and acoustic boundaries of the performance space (the vast interior of the BSF) were initially 'traced' from drawings and photographs to create a 3D digital model, which was used to run ray-tracing simulations that demonstrate how reflected sound 'occupies' the space. The results of the simulations revealed the spatial and acoustic capacities of the architecture, informing the positioning of performers in a way which capitalises on the unique reverberation profile of the BSF. In this research, composition is viewed as a mechanism for inquiry rather than a means of expressing known things. Thus, acknowledging the compositional process is a crucial part of the work. Like the others in the series, C002 isn't intended to be a 'finished' product. It learns with every performance and serves as a tool for fostering creative resonances between the simultaneous practices of making space and sound in architecture and music, respectively.

Rehearsing and simulating space

The project was composed at a physical distance from both the anechoic chamber and the BSF. Despite a distant memory of a visit to the BSF as a tourist several years prior to this project, it wasn't feasible to revisit the space to

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[16] Brant, *Textures and Timbres: An Orchestrator's Handbook*. Pxii

[17] Goodman, *Languages of Art: An Approach to a Theory of Symbols*. Pp179 – 192.

[18] Cook, *Beyond the Score: Music as Performance*. P240.

[19] Ibid. P241.

[20] C002 exists as part of a sequence of iterative works which learn from each other, and each pose a different question with regard to discovering and developing active relationships between the practices of making space and making sound.

conduct tests and gather information before starting the composition. Access to the BSF for the performance of C002 was granted through an Australian Research Council-funded project which quantifiably examined the acoustic condition of the space.[21] Consequently, researcher Dr Jim Barbour was able to provide several previously recorded impulse responses (IR)[22] from the space as an acoustic reference during the composition process.

While useful, the Impulse Responses (IRs) captured have certain limitations which need to be considered. Firstly, they are limited to the locations where they were physically captured. Also, since the BSF interior was under construction during the capture, the IRs only represent a snapshot of the acoustic condition at that time. However, the IRs allowed for the simulation of the sound of the space during music composition. This was done by convolving the IRs with a series of dry MIDI outputs from notation software, Sibelius.[23] This method was particularly useful in the early stages to understand how different instruments might sound in the space and to identify the appropriate timbral and tonal ranges that would capitalise on the unique reflection profile of the space. By visualising the IRs in a spectral frequency display,[24] it was also possible to visually verify which frequencies were the most present in the reflections, and for how long.[25]

To explore performer locations more flexibly, a digital model of the space was used for ray-traced acoustic simulations, akin to the auditory equivalent of an architectural render or physical model.[26] These simulations generated impulse responses which helped to auralise various spatialisation options. With Pachyderm, it was also possible to visualise early reflections, identifying areas of intensity, especially in the more intimate peripheral spaces of the BSF where reflection distances and times are shorter due to smaller surface distances. The different computer programmes (listed earlier) each had their own advantages and limitations. In purely subjective terms CATT Acoustic was arguably the most accurate, sounding the most like the eventual performance. EAR for Blender, despite being the least aesthetically like the eventual real performance (and sadly no longer supported), was especially useful in the sculptural and iterative process of quickly moving sound sources around virtually, to sketch out the different options. This process is perhaps the digital equivalent of what musicians and composers did centuries ago, where they operated through trial and error, working directly and empirically within the space. This was before acoustics became a specialised field, and before it was possible to make calculations remotely from the physical site. Since the resulting auralisations were subtly yet noticeably different, they weren't treated as an absolute measure of the sound in the actual space. Instead, they aided in constructing a relational picture, comparing outputs between computer programs and positions. This approach provided a sense of how the sound might change between locations and positions within these spaces, rather than providing reliability for the certainty of the eventual sound.

Typically, such tools are used in the design of buildings for music, rather than in the composition of the music itself. At this point, it is worth casting a critical ear across these tools. With non-visual media, it is easy to forget that the outputs are merely representations, and not reality. Researcher Jonathan Sterne helpfully acknowledges that acoustic behaviours are complex, stating that 'so many things are happening in so many different ways that they cannot be calculated or captured by any modern computing device…'.[27] Sound doesn't neatly travel in straight lines and many simulation tools don't account for complex wave behaviours,[28] so these tools can only ever provide an impression of the sound in the space. This is not a substitute for, or as rich or as complex as the reality. C002 presented an opportunity to use and critique this acoustic simulation technology from the viewpoint of a composer with

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[21] The project is titled 'Architecture for Improved Auditory Performance in the Age of Digital Manufacturing'

[22] Jim gained his PhD from the Royal Melbourne Institute of Technology (RMIT) in 2017 with his dissertation titled: 'Spatial audio engineering: exploring height in acoustic space' – and has explored a range of recording techniques for capturing the sound of the uniquely tall interior of the BSF.

[23] Avid, *Music Notation Software – Sibelius*.

[24] Adobe Audition and SPEAR (by Michael Klingbeil) were used for visualising the existing IRs.

[25] Spectrum analysis tools in computer programme 'Audacity' were also used to get a more fine grain understanding of what was visibly apparent in the spectral frequency display.

[26] For the anechoic chamber, there was no need for a simulation model, as it is completely absorbent to sound.

[27] Sterne, 'Space within Space: Artificial Reverb and the Detachable Echo'. P122.

[28] Dalenbäck, 'Whitepaper: What Is Geometrical Acoustics (GA)?'

architecturally sensitive expectations, not a building designer or client seeking an audible representation of a yet unrealised space, which is the typical use of these simulation tools.

The composition process relied less on the numerical data output from simulations, such as early reflection and reverberation times, and more on a sculptural approach. The content was developed based on how it sounded using auralisations and spectral frequency displays, rather than checking exact pitches or durations. For playback of simulated content, stereo headphones were primarily used. However, for higher resolution and spatially immersive playback, the SoundSpace[29] at Max Fordham was utilised. This was particularly helpful in understanding how the sound changes with differences in the performers' positions. By modelling these variations in advance of the eventual physical performance, it allowed for greater exploration and iteration. This led to a more informed period of experimentation once in the physical space. For instance, it was discovered that some positions would yield more dramatic results than others.

Articulating space

From studying Gaudi's models and drawings, researchers have concluded that Gaudi always intended the BSF to play a role in the projection and propagation of music, particularly the sound of the tubular bells that he also designed. One particular study proposes that the geometry of the louvered windows, in relation to Gaudi's tubular bell design and their sound radiation, would allow sound to propagate throughout the city, therefore turning the BSF into a giant instrument.[30] Inside this instrument, the vast space, and reflective materials - both for sound and light - enhance and elongate the presence of sound, surrounding the listener and articulating as if another architectural material. The architecture is then asking music to help articulate its presence akin to the way that the materials of stone and glass might form space in a physically tangible way. This creates a reciprocity between sound and space, where the architecture contributes to the music through its acoustic response and support for sound spatialisation, and the music, in turn, contributes to the completion or activation of the architecture. The building might therefore be considered as a performer as much as it is an instrument, activated by compositional intent, and perhaps embodying both roles simultaneously.

As mentioned at the beginning of this chapter, the choice of instrumentation was partially guided by the need to align the tonal range of the performed music with the frequencies that the building is most reflective to (as confirmed by the IRs). The timbral characteristics of the instruments were also important: The Violin and Cello have the capacity to sound both similar to, or distinct from each other, based on aspects like playing technique and tonal range. The capitalisation of their timbral similarity, when coupled with a highly reflective acoustic condition, has the effect of 'filling up' the space. A principle that draws on Brant's experimentation with the spatialisation of performers.[31]
On the other hand, distinguishing their timbral differences separates the two voices and aids in examining the audible clarity and potential musical value of sound localisation in highly reverberant environments. In the BSF, the effect of spatialisation is particularly complex to understand as there is a directional ambiguity, partially attributed to the long early reflections as a result of the large distances between acoustically reflective surfaces.

Two crucial parameters for articulating space through sound are the distance and direction between sound sources or performers, and between the sound sources and the listener or microphone. In the case of the BSF, locating the direction of the sound source is difficult due to the high level of acoustic reflection. However, the effect of distance is audibly clear, especially in the way that larger distances between the performers and the microphone seem to produce a longer attack, even for shorter notes. For example, within the acoustically dry space of the anechoic chamber, the notes in bars 60-63 were heard sequentially, and distinct from each other, forming a perceivable melodic line. However, when the same passage was played in the BSF, the attack of the individual notes was noticeably softer. It was also partially obscured by the decay of the preceding notes, making the passage sound more like an overlay of notes from uncertain spatial and temporal origins. The resulting sound therefore had a more harmonic than melodic aesthetic,

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[29] 'Acoustics - Max Fordham - SoundSpace'.
[30] Yoshikawa and Narita, 'The Sagrada Familia Cathedral Where Gaudi Envisaged His Bell Music'.
[31] Brant, 'Space as an Essential Aspect of Musical Composition'. P238.

influenced by a combination of the distance between the performers and the microphone, and the reflectivity of the space.

The positioning of the performers was first rehearsed in the digital models, allowing for the exploration of several different locations for comparison. The eventual performer locations were instructed as follows:

<FIGURE 1 HERE>

'BSF performance Layout Diagrams' Emma-Kate Matthews, 2017.

First, the cello and violin were positioned 10 metres apart horizontally and 17 metres high on a balcony. Next, they remained at the same height but were moved 50 metres apart from each other. Then, both instruments were moved to the ground floor, with the cello near the altar and the violin at the other end of the nave. After, they were placed opposite each other on the ground floor, only 10 metres apart and close to the microphone. Finally, the instruments were separated again, positioned 20 metres high and slightly over 60 metres apart.

The relationship between performer positions and the corresponding acoustic reflections resulted in distinct differences between each position. These differences were more significant than the simulations predicted. The large distances also affected the musicians' approach to the music, particularly when the distances were greater. For example, the tempo we heard in the Sagrada Familia was noticeably slower than in the anechoic chamber. In the Anechoic chamber at 80 BPM, the piece was complete within 5 minutes, in line with the notation. However, in the BSF each performance lasted around 6 minutes and 20 seconds, indicating a tempo closer to 60 BPM. This discrepancy could be due to the musicians waiting for the acoustic reflections to conclude, or perhaps they were simply playing more cautiously as they couldn't see each other for visual verification of each other's starting tempo. It could also result from the delay caused by distance.[32] When asked to reflect on these temporal differences, both musicians said they had not perceived a difference in tempo between the Anechoic chamber and the BSF performances, and they certainly did not make a conscious decision to slow down. The violinist then compared playing in the BSF to walking underwater, noting that the sound sometimes behaved unpredictably. The simulations that were ran beforehand failed to detect such nuances, as we know that these tools can't predict human behaviour or more complex wave behaviours.

Despite the value placed on the physical immediacy of live performance and the challenges in capturing spatiality in sound recording, it was still recorded to provide a retrospective reference for the variations between each performance. The recording was made using a microphone engineered by Dr. Jim Barbour, a project collaborator. His research primarily involves capturing the verticality of space in ambisonic recordings. To achieve this, he devised a method using a tall stack of 12 microphones, arranged radially in plan, to capture the sound's spatiality under one of the highest parts of the Sagrada Familia's interior.

<FIGURE 2 HERE>

Left to right: Jim Barbour with ambisonic microphone array'; view of microphone array from balcony; microphone against the altar. Emma-Kate Matthews & Finneas Catling, 2017.

The ambisonic microphone was always kept static, near the altar, where the original impulse response files were created. By this rationale, the microphone's position could be considered the 'optimum' listening point as it is the theoretical 'standing point' from which the music was constructed. This is like a measured perspective, a familiar concept to architects and visual artists, in which the horizon line and vanishing points are set, and a standing point is decided as the 'viewer' (or in this case, the listener). When viewing a perspectival drawing or listening to a sound recording, the viewer or listener is inevitably implicated in the scene. This suggests there might be an 'optimum' position for viewing or listening. This concept is particularly emphasised in anamorphic art, where visual content only assembles, or makes sense from a certain viewing position. Spatial composer Brant maintained that in his spatialised compositions, where the performers' locations are as meticulously determined as the music they perform, no single

[32] This possibility is discussed in detail the following section.

listening, or performer position is considered optimal.[33] In this research, the aim of placing performers in different locations within the same space is not to find a single 'optimum' arrangement. Instead, the goal is to understand how the interplay between musical content and performer placement can activate the space. This process can tease out both conceptual and physical resonances between sound and space, using music composition and performance as the medium.

Activating space

There are of course many ways to explore creative relationships between sound and space, especially when aspects such as architectural acoustics are considered on both poetic and technical terms. C002 offers just one of countless other approaches that similarly have the capacity to reveal alternative resonances. The compositional methods employed in this research combine both calculative and intuitive processes and the resulting tacit knowledge is primarily obtained empirically, making it difficult to explain in explicit terms. However, it's still valuable to consider certain specific compositional decisions and their impact on charging the music with the ability to form a dialogue with the space, starting with an examination of the piece, section by section:

The piece begins with a short, ***fff*** chord, immediately followed by a pause. This initial gesture is like a question to the architecture, somewhat similar to an IR, soliciting an acoustic response. This gesture recurs throughout the piece, repeating the question in subtly different ways. It also serves as a reference point for the performers to synchronise, as there is no conductor, due to the inability to rely on clear visual cues.[34] The notes chosen for this chord, C#2 (69.3Hz)[35] on the cello and G3 (196Hz), F4 (349.23Hz) on the violin, were selected based on the frequency range most prevalent in the IRs. This was also balanced with the ease of playing double stops on the instrument. Open or near-open strings were favoured to maximise the instrument's resonant capacity and enhance the interaction between the sound and the architecture. Section A sets the tonal range for the entire piece, influenced more by the acoustic behaviour of the space than by conventional logics of Western music theory. It primarily features long drones that swell and recede in dynamic, dovetailing with the decay of the initial shorter 'stabs'. Throughout this section, the violin maintains a timbral distance from the cello by playing in a different octave and alternating between sul tasto and sul pont[36] bowing positions. The section culminates in a longer chord which increases in dynamic from ***ppp*** to ***fff*** followed by another 'stab' similar to the opening gesture, but with different notes in the cello. The slight change in note selection, now including C2 (65.41Hz) and C#3 (138.59Hz), aims to investigate the range of frequencies to which the building responds, instead of trying to pinpoint specific pitches as narrowly defined entities.
The intentional use of 'dissonant' intervals, such as a minor 9th in this case, is aimed at generating as much sonic material as possible during these IR-like moments. Choosing dissonant combinations reduces the potential for tonal ambiguity, as there are fewer shared partials between notes. This makes it easier to pinpoint which musical inputs are being affected by the architecture, how and to what extent.

Section B delves deeper into the effect of attack and dynamic variation on the space. Starting at bar 14, this section features a shorter series of dynamic swells on various notes within the established range from the first section. This aids in understanding the role of reverberation in binding harmonic content. Altering the length of the note tests the point at which individual notes become audibly distinguishable, amidst the 'blending' effect of the acoustic reflections.

In Section C, at Bar 29, the cello starts playing in the same pitch range as the violin. It uses an open C string to create a continuous 'background' or 'horizon' line, occasionally accentuated by a harmonic on the open string. This section is deliberately more tonally ambiguous. The two voices partially merge, testing the spatial separation's capacity to preserve the clarity of individual voices. The aim here is to determine the threshold at which the acoustic response begins to obscure this separation.

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[33] Brant, 'Space as an Essential Aspect of Musical Composition'. P224.
[34] This device became particularly crucial in the BSF when the distances between the performers were large enough to hinder attempts to play 'together'.
[35] Frequencies are based on the equal-tempered scale.
[36] Sul tasto bowing is closer to the fingerboard and sul pont is closer to the bridge.

Starting at bar 39, Section D introduces intermittent, short-note melodies in the violin. These are deliberately 'choppy' to contrast with the low-pitch continuity provided by the cello. Occasionally, the violin reinforces this continuity with drone-like material between the intermittent melodies. This creates an oscillation between the merging and separation of voices, testing the temporal thresholds at which the two voices become audibly distinct.

At section E, bar 60, the content established in earlier sections is fragmented and thrown back and forth between the violin and cello. This highlights the relationship between spatial separation, which emphasises each instrument's voice, and the acoustic response of the space, which in contrast, blends these voices together.

In section F at bar 64, the alternation of material continues, marked by frequent swells in dynamic that mark a gradual lengthening of the notes again, and marking the transition into section G at bar 82. Here, we return to the drone-like content like that was played at the beginning, but with both instruments playing in the same octave this time. The piece concludes with much more tonally ambiguous material, where it is intentionally difficult to distinguish whether the articulation of the music is produced by the musicians, or the building. For instance, it becomes difficult to determine if a slow attack is caused by the musician's articulation, distance from the microphone, acoustic response, or a combination of all these things. At this stage, the music becomes aligned with the space, and the building performs in unison with the musicians.

While it was possible to examine these sections as separate entities, a conscious decision was made to organise them into a cohesive narrative within a 'piece' of music. This decision was driven by the nature of the analysis, which revolves around comparing performances in different spaces and configurations. Maintaining a consistent sequence in the structure of each rendition offers a more straightforward framework for making meaningful comparisons.

Observing spationsonic relationships

The development of these musical strategies was influenced by feedback from digital simulations, intuitive knowledge from the experience of previous projects, and studying Brant's work. Extensive scientific research has also been conducted by others to understand how acoustic response affects not only the behaviour of sound in the space, but also that of the performers. It has been observed that performers of string instruments frequently adjust aspects of their playing, such as tempo, loudness, and bowing pressure, in response to changes in room response.[37] This research was utilised to anticipate such changes. Following performances in the anechoic chamber and BSF, many empirical observations were also made that exceeded or were not highlighted by the digital rehearsals. The recording of and reflection on such observations are crucial in the development of spatiosonic practice. To summarise a few of the most notable:

A strong connection was observed between performer distances and the tempo of their performance. with greater distances corresponding to a slower pace. This phenomenon can be reasonably attributed to the inherent delay in sound propagation over large distances between the musicians. To illustrate, when the performers were positioned 64 metres apart, where sound travels at a rate of 343 metres per second, the resulting delay amounts to approximately 0.18 seconds. Given a tempo of 80 beats per minute, where a quaver lasts about 0.75 seconds, the delay caused by the distance equates to roughly a semiquaver. This delay proves consequential enough to perceptibly influence temporal precision in the performances. This effect is particularly prominent during passages that contain more 'melodic' content from section C onwards, where the shorter notes appear to exaggerate the impact of delay due to distance.

The large distances between interior surfaces also contribute to longer early reflections. At the scale of the BSF, this appears to noticeably soften the attack of each sounding note making individual notes in melodic phrases less distinct and harder to locate in time and space. The resulting sound is blended, immersive, and therefore harmonically rich. This challenges Brant's observation that 'spatial separation destroys harmony and ensemble.'[38] In the case of C002, the extreme acoustic condition of Sagrada Família's interior disrupts the effect of physically separating sound sources,

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[37] Ueno, Kato, and Kawai, 'Effect of Room Acoustics on Musicians' Performance. Part I: Experimental Investigation with a Conceptual Model'.

[38] Gagne and Caras, *Soundpieces: Interviews with American Composers*. P60.

meaning that the effect of spatial separation is not distinct from acoustic condition, as Brant's theory suggests. The relationship C002 examines between spatial separation and acoustic response, builds on Brant's work. While Brant neither formally studied architectural acoustics nor explicitly acknowledged acoustics in his work, he recognised the lack of cross-pollination between sonic and spatial practices. He suggested starting with pedagogy: ...it would be worthwhile if you could find the time sometime to get a book on acoustics, musical acoustics, and read about these things, which every musician should learn in music school, and none of them know about it...' [39] This observation is key in enhancing the exchange of knowledge, tools, and skills between spatial and sonic disciplines. A shared grasp of both technical and intuitive acoustic vocabulary would facilitate this process.

A more nuanced observation concerning the effect of reverberation is in the behaviour and presence of partials[40] after the initial attack of some of the more frequency rich notes (typically those played on open strings). Some partials decayed quickly, whilst others appeared to continue reflecting long after the fundamental tone had faded. Once again, the spectral frequency display of the recordings was helpful in visually verifying the way that these partials were behaving in the space as the ephemerality of sonic phenomena often makes it difficult to comprehend more subtle details of what is being heard. After the first chord (which includes a C#2 (69.3Hz), G3 (196Hz), and F4 (349.23Hz)), these lingering partials can be heard. While only the G is played on an open string, the remaining notes are played low on the fingerboard, with a firmly pressed finger and long length of vibrating string, thus enhancing the presence of partials.[41] Following this first 'stab,' partials at frequencies of C3 (130.81Hz), G4 (392Hz), and D5 (587.33Hz) remain audible, where others reliably decay more swiftly. This is consistent with IRs which indicate that the space is particularly reflective to frequencies within this range. This may explain why the fundamentals outside of this range were decaying before their upper partials. These enduring 'after images' are reminiscent of the anecdote by Bagenall that inspired this research, suggesting that the building contributes its own voice to the music.

While this research does not delve into the scientific specifics of these phenomena, it benefits from the tools, methods, and vocabulary used in acoustic and architectural practice to gain a holistic understanding of what the space is doing to the music (and the musicians who play it). It seems that aspects as fundamental to music as tempo, timbre, and even pitch (due to the later decay of partials over the fundamentals) change significantly between the anechoic chamber and the BSF. The music was specifically composed to tease out these differences. Therefore, the musical logics that play out in this composition are governed by architectural logics over those dictated by traditional western music theory. The resulting musical aesthetic, a popular topic in musical discourse, arises from a combination of spatially driven musical logics and the audible acoustic and spatial traits of the architecture in the eventual performance. This composition, along with others in the series, collaborates with architecture to make music, rather than simply performing for or at it. This music not only projects outwardly during its performance, but also learns, discovers, and gains knowledge in return.

Conclusions

When we empower architecture to become an active participant in the performance of music, rather than a mere container, we enter more nuanced explorations of the interplay between sound and space. This transcends quantifiable metrics, inviting a subjective and sometimes uncomfortable dialogue among architectural, musical, and acoustic practices. By doing so, we open fresh avenues for creative expression, and develop new practical and conceptual methods for ways in which architecture and music can relate and contribute to one another. This dynamic approach fosters innovation in composition and ensures that the architectural design practices remain agile and aligned with the disciplines it has historically synergised with. It nurtures an ongoing dialogue where architecture continually adapts to music's needs, and music acknowledges architecture's profound influence on its performance and composition.

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[39] Brant and Crawford, An interview with Henry Brant: Spatial Music to Evoke the New Stresses, Layered Insanities, and Multidirectional Assaults of Contemporary Life on The Spirit.

[40] In music, a 'partial' is a component of the harmonic series which helps define the timbre or tone quality of an instrument. The fundamental frequency serves as the first partial, with subsequent partials being multiples of this fundamental frequency. The relationships between these partials can be either harmonic, or inharmonic.

[41] Meyer, *Acoustics and the Performance of Music: Manual for Acousticians, Audio Engineers, Musicians, Architects and Musical Instrument Makers: Manual for ... (Modern Acoustics and Signal Processing)*. P88.

The stark contrast between the anechoic chamber and the BSF is pivotal, highlighting the relationships between sound and space. This extreme difference emphasises these relationships, much like examining something under a microscope to reveal previously unnoticed details. The insights from this project go beyond its extreme setting and can be applied to less intense scenarios, providing valuable lessons on optimising acoustic conditions or refining methods to activate architecture more directly. In addition, the project aids in developing tools and methodologies that benefit both composers and architects. By understanding how to effectively work with space and sound, intuitive visual aids and listening techniques can be developed. These resources, nurtured through this project, can be used in future projects where sound and space are equally valued components, ensuring a harmonious integration of these elements.

Sound files

These sounds are available on the Routledge E-Book page and a full-length recording is available at Emma-Kate's own website: https://www.ekm.works/construction002

MATTHEWS_1-ANECHOIC
Recording of opening few bars of C002, in the anechoic chamber

MATTHEWS_2-GENERIC-LARGE-CATHEDERAL
Anechoic recording of opening few bars of C002 processed with a 'generic large cathederal' effect in ableton Live

MATTHEWS_3-CATT-POS1
Anechoic recording of opening few bars of C002 convolved with an IR simulated by CATT Acoustic, with musicians in position 1

MATTHEWS_4-EAR-POS1
Anechoic recording of opening few bars of C002 convolved with an IR simulated by EAR for Blender, with musicians in position 1

MATTHEWS_5-ACTUAL-POS1
Recording of opening few bars of C002 as physically captured in the Sagrada Familia, with musicians in position 1

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