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Rhythm, Scale, and Liminality:
Sonic composition and interdisciplinary artwork developed in response to architectural contexts.

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Abstract

This research explores perceived connections between architecture and music, and considers how these ideas can inform interdisciplinary creative practice that is developed in response to specific architectural contexts.

Whilst the relationship between architecture and music can be perceived as an abstract translation between spatial and temporal art forms, this research was established on the premise that the experience of either discipline is necessarily spatial *and* temporal. As such, a research methodology was selected that aimed to encompass both of these elements.

Through an iterative process of inter-related contextual review and practice-based research, a creative approach was undertaken that defined three connected methods, "rhythm", "scale", and "liminality". Within the practical projects, "rhythm" was employed as a tool for engaging with external architectural form, and "scale" as a method for articulating our subjective experience of interior space. The third area of practical research explored the relationship between inside and outside space, and the role of "liminality" in shaping our experience of architectural context.

Each practical project aimed to incorporate elements of both aesthetic and numerical interpretations of architectural context, and considered the significance of using digital tools and processes in their creative realisation. Four research findings were derived from a summary of the observations associated with each practical project and its associated contextual review.

The first finding proposes that rhythm, scale, and liminality can provide the basis of a transferable framework that can function as a spatial and

temporal creative toolset, with the flexibility to incorporate both qualitative and quantitative interpretations of architectural contexts.

The second finding concerns the relationship between "openings" and "openness" in both architecture and sound/music, in which the quantitative form provides a frame for qualitative experience. As an extension of this idea, it is proposed that any discrepancy between the range of our visual and acoustic horizons can provide an inconsistent aesthetic experience of "openness".

A third finding relates to the application of digital and mobile technologies in creating this type of work, and how these tools can provide opportunities for audiences to personalise their aesthetic (qualitative) experience, despite using technology that is inherently numerical (quantitative) in its approach to information.

Finally, the practitioner experience of applying these methods in multiple projects led to a fourth finding: that using this framework of rhythm, scale and liminality not only provides a method for developing context-specific creative practice, but that it can also function as a valuable practice-based research tool capable of providing additional insight when investigating a specific location or social context.

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1 Introduction

1.1 Research overview

> "The speculations about the relation between music and architecture are probably as old as both arts themselves." (Sterken, 2007: 31)

This research process builds on the experience of working as a practitioner who has previously developed a series of musical and interdisciplinary creative works in response to different architectural contexts. The theme was initially inspired by the notion that architects can invoke a sense of rhythm and dynamics through the built environment, which in turn led to a wider interest in how the relationship between architecture and music has been interpreted over time, and how these observations can inform contemporary sonic composition and interdisciplinary practice.

Whilst my own creative practice often incorporates aspects of music composition and sonic art, the aim is typically to allow the concept and context to dictate the art form through which the work is presented. As a result of this, the practical projects documented in this thesis span several different media, including video, digital, sculpture, wearable and mobile art, live performance, and animation.

The following overview outlines some of the central principles that have underpinned the research process, describes the primary research aims and questions, and provides a general overview of the thesis structure.

1.1.1 Space and time

Perceived connections between architecture and music have often been framed as a translation between what have been traditionally

labelled as spatial and temporal art forms respectively (Hanoch-Roe, 2003: 69). This is evidenced by Elizabeth Martin's suggestion that:

> "Architecture represents the art of design in space; music, the art of design in time." (Martin, 1994: 8)

However, for the purposes of this research, the position is taken that the experience of either discipline (architecture or music), is necessarily both spatial *and* temporal in nature.

> "Time and space… exert a reciprocal action: they measure themselves against one another" (Lefebvre, 2013: 18)

For sound, this is true on both a micro and a macro level, from the oscillations of a sound wave, to the way a sound travels through, and responds to, its environment. Sound travels a quantifiable distance over time, its speed and direction varying depending on the temperature and medium through which it is travelling, and for us to experience a sound we must place ourselves in its path. The nature of the sound we hear is entirely dependent on the space it inhabits, or to borrow the title of Will Schrimshaw's PhD thesis, "A sound takes place" (Schrimshaw, 2011).

The seemingly static architectural *form* adopts a temporal dimension through the dynamic nature of architectural *space*, and the layer-upon-layer of chronological events this encompasses. Whether observing the opening of a window or seasonal environmental fluctuations, stepping across a threshold or a long-term habitation, the experience of architectural space is invariably temporal. So whilst for the listening experience "a sound takes place", one could also say that for the architectural experience, "a place takes time".

1.1.2 Aesthetic effects and numerical principles

As this research argues that architectural and musical experience are each both spatial *and* temporal in nature, the process explores methods that aim to accommodate both of these elements. Previous attempts at doing this have been described as falling into two opposing methods — "the intellectual and the phenomenological" (Sterken, 2007: 31) or alternatively "analogy and utility" (Ostwald, 2014: 65). Sterken has described the different approaches as either trying to "shape architectural and musical form according to the same numerical principles" or responding to a context's "aesthetic effects and its immersive power" (Sterken, 2007: 31).

However, problems arise in attempting to clearly define a separation between these two schools of thought in an objective manner. For example, one person may experience sounds in a highly "atmospheric" reverberant acoustic space, and attribute their aesthetic experience in qualitative terms to the "immersive power" of their surroundings. Someone else may experience the same reverberant space, and attribute their aesthetic experience in quantitative terms to the geometric proportions ("numerical principles") of their surroundings, and the measurable acoustic properties of the reflective and absorbent materials that form the surrounding space. These qualitative and quantitative perspectives can be understood in the historical context of Schelling's philosophy of art, in which he stated that:

> "All fine art is the imagination of the infinite into the finite, of the ideal into the real" (Schelling, 1859: 629)

This issue of realising "infinite" aesthetic concepts through "finite" and quantifiable media is echoed in the words of architect Louis Kahn:

"The poet is one who starts from the seat of the unmeasurable and travels towards the measurable, but who keeps the force of the unmeasurable with him at all times" (Lobell and Kahn, 2008: 14; Lutz, 2014: 69)

With these perspectives in mind, this research explores connections between architecture and music with a focus on methods that not only aim to encompass the spatial and temporal aspects of each discipline, and that can also accommodate both qualitative and quantitative methods of creative interpretation and expression.

1.1.3 Research aims and questions

This research was undertaken with the aim of exploring two main areas, each with the ambition of addressing an associated research question.

The first aim was to examine the parallels that have been drawn between architecture and music, and the different methods that have been used to connect the two disciplines. This included making observations concerning how the two art forms have been associated in both theory and practice, and looking at historical and contemporary examples in order to understand where this current research fits within the evolution of the field. Building on the themes outlined in the research overview, this aspect of the work was designed to address the first research question:

1. How have perceived connections between architecture and music been interpreted and presented in both experiential and numerical terms?

The second overarching aim of the research was to investigate ways in which the methods observed through research question 1 can inform sonic composition and interdisciplinary creative practice when

responding to architectural contexts. This aspect of the research focused on how these observations can directly inform an iterative creative process, employing methods that in some way aim to bridge qualitative and quantitative means. The practical projects produced for this aspect of the research span several different media, including music composition and sound art, video, sculpture, wearable and mobile art, live performance, and animation — with a particular focus on the role of digital tools and techniques when employing these principles as a creative methodology. This section of the study aimed to address the second research question:

> 2. In what ways can these approaches be combined to inform sonic composition and interdisciplinary creative practice when responding to architectural contexts?

In addressing these two questions, the research intended to provide both contextual information and a practical framework for contemporary composers and interdisciplinary practitioners working in response to architectural contexts.

1.1.4 Thesis overview

This thesis is structured around two main bodies of work, consisting of a contextual review in chapter 2 **– Architecture and Music**, and the documentation of practice-based research projects in the **Practical and Further Contextual Research** chapters 3 - 6**.**

Chapter 1 – **Introduction** provides an overview of the research, some background information, and the role of Tim Ingold's "thinking through making" (Ingold, 2013: 6) in developing a context-based creative research methodology.

Chapter 2 – **Architecture and Music** provides a literature and contextual review, following a chronological evolution of the manner in which key theorists and practitioners have sought to draw parallels between architectural and sonic work through both aesthetic and numerical approaches.

Chapters 3 - 6 – The **Practical and Further Contextual Research** section is split into the three main research themes that emerged through the combination of contextual review and iterative practical research, which are **Rhythm**, **Scale**, and **Liminality**. Each of these sections incorporates documentation of the practical research developed in response to each theme, observations made in response to developing the work, and additional contextual review tailored to the research theme.

Chapter 7 **– Findings and Conclusions** draws together key themes from the observations made in response to each of the research themes (Rhythm, Scale and Liminality), distilling them into a number of findings. These include proposing a creative framework for responding to architectural contexts that is based on our experience of visual and acoustic horizons and the relationship between quantifiable "openings" and unquantifiable "openness".

1.2 Research methodology

1.2.1 Overview

The methodology chosen for this research combines contextual and literature review with creative practice, with each aspect informing the nature of the other as the process evolved, as seen in many practice-led research projects in recent years. Examples of this include PhD research by sound artist Tim Shaw (Shaw, 2018) and architect Nadia Mounajjed (Mounajjed, 2007), each of whom developed new creative

works as a method of exploring their surroundings. The work of each of these researchers is expanded upon later in this thesis.

A central theme of the research is the nature of context-specific creative practice, and the aim was not only to use the practical work as a research tool for interrogating issues pertaining to site and context, but also to use the observations to refine the creative process itself. As such, the ambitions for this work can been seen as spanning Christopher Frayling's distinctions between research *through* art and design, and research *for* art and design (Frayling and Royal College of Art, 1993: 5).

Sound artist Tim Shaw successfully framed his practice-based research in relation to Tim Ingold's writings on the role of *making*, applying Ingold's thoughts on working with traditional materials to the media of Shaw's own work - sound and technology (Shaw, 2018: 11, 16). A central theme of Ingold's argument is that theorists and craftspeople perceive the role of making in very different ways, in which the theorist "*makes through thinking*" and the craftsperson "*thinks through making*" (Ingold, 2013: 6). The ambition for this research was to incorporate aspects of each of these perspectives, with the aim that observations from each method influenced the other at every stage of the process, creating a bridge between the two approaches.

Ingold's interdisciplinary approach in "Making: Anthropology, Archaeology, Art and Architecture" also provided a useful framework for this study with respect to architectural contexts. Ingold's work also highlights the issue of architecture being traditionally interpreted in terms of its built objects, ignoring the resulting environments they provide and how they are perceived (Ingold, 2013: 10), noting that this has also typically been the case with visual art. This observation is reminiscent of Beryl Graham's description of a participatory digital art work by "The People Speak", explaining that the "important intent of the

artwork is clearly not an object but a process" (Graham, 2013). Graham highlights how systems-based and participatory digital artworks pay particular attention to these issues, and this was an important influence on the methodology applied for this practice-based research, which looks primarily at creative process rather than specific art forms or media.

Subsequently, throughout the research period documented here, each practical project attempted to bridge this perceived dualism of architecture as both a static object, and as a dynamic experience. In exploring this, aspects of architectural phenomenology became a recurrent theme, with a concerted effort made to consider the experiential nature of the documented practical projects. This aligns with the broadly relativist ontological perspective that underpinned the research process. The reasoning for taking this approach was simply that works of architecture, like music, or any other art form, do not exist in a vacuum. Regardless of the perceived clarity of the underlying creative intent, our interpretation of the work itself (and any "meaning" we might infer from it) will inevitably be informed by our own personal experience and what we bring individually and collectively to the architectural or musical event, based on the prior knowledge and cultural expectations that shape our understanding of the world around us. As such, this notion of personal experience creating multiple realities is coherent with the relativist ontology adopted in this research. In his work on "Musicking", Christopher Small has suggested that "everyone's musical experience is valid" (Small, 2010: 13), and the same can be said for architectural experience.

As previously explained, an important aspect of the research methodology was to study observed links between architecture and music, considering how these connections might inform contemporary interdisciplinary practice, and exploring their potential through real world creative interventions. In doing this, the aim was to avoid distinguishing

between architectural and sonic works as spatial and temporal respectively, as this would have reinforced the notion of architecture as a static spatial object, and sound and music being purely temporal events that are independent of their surroundings. Therefore (and as mentioned previously), this research assumed the perspective that experience of either architecture or sound/music are necessarily both spatial *and* temporal, and as such the research sets out to establish a toolset that is capable of bridging these two elements. This is contextualised with references to Henri Lefebvre's concept of "Rhythmanalysis" (Lefebvre, 2013), interpretations of Henri Bergson's thoughts on scale (Wells, 2013: 6), and Gaston Bachelard's writing on the inside-outside dialectic (Bachelard and Jolas, 1994: 212).

These concepts provided the substance for the methodological framework documented in this thesis. At each stage in the research process, observations were made in response to contextual and literary review, and to the experience of developing my own associated practical research projects. By observing potential issues and knowledge gaps at regular intervals, a new theme was established for the next period of research. This open process resulted in establishing three emergent themes based on the understanding and learning provided by the previous topic, which were Rhythm (section 4), Scale (section 5) and Liminality (section 6), with the reasoning for each development outlined in the observations of the preceding chapter.

The result of this process was a shift away from methodologies that simply translate between the temporal and the spatial, towards an approach that aimed to encompass what Louis Kahn has described as the "measurable" and the "unmeasurable" (Lobell and Kahn, 2008: 6) – the quantitative elements of the architectural, sonic, or art "object", as well as the subjective, qualitative perceptions of those who experience them. In the words of Jonathan Hill:

"The architect and the user both produce architecture, the former by design, the latter by use, as architecture is experienced, it is made by the user as much as the architect." (Hill, 1998: 6)

1.2.2 Scope

"First, this field of interest — it can't be called a discipline — is almost oceanic in scale and diversity; it can scarcely be said to have a unifying literature, and much less can it lay claim to a group of canonical objects or exponents or a set of methodological approaches. Second, it isn't new. Architectural and musical discourses have long been speaking about themselves in each other's terms". (Stone, 2015: 5)

This document is the written component of a practice-based PhD, the focus of which spans a number of complex creative disciplines. Subsequently, the resulting subject matter encompasses a breadth and depth that reaches far beyond the scope of this thesis. Therefore its primary focus is the documentation of research conducted through the process of my own creative practice, and the provision of inter-related contextual analysis detailing the key influences that informed the development of the works.

As a result, the scope of the thesis does not extend to an exhaustive study of the many theorists and practitioners who have sought to interrogate the connections between architecture, sound, and interdisciplinary practice. Neither does it attempt to give a detailed analysis of philosophical theories concerning spatiotemporal perception, or anthropological perspectives on the process of making. Nonetheless, selected contributions from these fields have been critical to the manner in which both the research process and creative practice have evolved, and their specific influence is referenced in order to contextualise the primary research conducted herein.

Whilst acknowledging that the nature of the creative practice itself is rooted in a process of abstraction (and as a result, embodies subjectivity at a fundamental level), the document aims to provide a transparent and transferable account of the research process, and of the manner in which the contextual evidence, creative practice, and observations from each stage of the project all informed the research trajectory and findings.

1.2.3 Responding to architectural contexts

This research explores connections between architecture and music, and how these observations can inform approaches to sonic composition and interdisciplinary artwork developed in response to "architectural contexts".

The term "architectural contexts" is intentionally broad, with the ambition that the findings within the research might be equally applicable to a building or site, a drawing or design process, an architectural theory or concept, a group experience or personal memory of a space, an intended use or re-appropriation, a permanent residence in a dwelling or a fleeting glance of a faćade. The term "site-specific" is not used, in order that the practical work could respond to aspects of architectural activity that were not necessarily realised as a completed building, and need not relate to a specific geographical location. In essence, this research considers site-specificity as merely one component of context-specificity, the latter encompassing a wider range of applications and interpretations for this type of creative practice. Subsequently, where some of the practical research projects documented in this thesis were developed in response to specific architectural sites, others were created in response to specific architectural themes. In these cases, the site in which the work is realised becomes an essential part of the piece, providing a unique character to the work and a means through

which to explore the underlying themes, but the site does not necessarily become the focus of the work itself.

This approach might be interpreted by Miwon Kwon as "problematizing received notions of site specificity" (Kwon, 2002: 2), but its flexibility made it suitable for the aims of this practice-based research.

Returning to Sven Sterken's observations concerning the use of either "the same numerical principles" or "aesthetic effects" (Sterken, 2007: 31) as a means of drawings associations between architecture and music, these approaches (and combinations thereof) formed the initial basis of the practical responses produced throughout the research. The ambition to overcome this qualitative/quantitative dualism was highly influential on the over-arching process undertaken.

In his book "Archetypes in Architecture", Thomas Thiis-Evensen stated that:

> "Typically, first impressions of a building take the form of purely qualitative evaluations." (Thiis-Evensen, 1987: 15)

However, a simple (and entirely unscientific) test placed some doubt on this assertion, when I asked the closest person for a one-word description of a familiar local building (a large art gallery) and received the immediate response "big". Similarly, the follow-up question asking about an equally familiar wooden structure next to a boating lake (without any additional context) was immediately described as "small". Thiis-Evensen may be correct in saying that our "first *impression*" is qualitative, but in communicating that aesthetic response, our "first *descriptor*" may well be quantitative.

A process of quantification is virtually unavoidable for the architect at some point in their working process. That is not to suggest in any way

that the expansive role of an architect can be reduced to "numerical principles", but merely notes the pragmatic requirements for architects to consolidate their ideas about space in geometric terms in order for them to be communicated and realised. This is captured by Louis Kahn in another quote about moving between the "measurable" and the "unmeasurable":

> "The only way you can build, the only way you can get the building into being, is through the measurable… But in the end, when the building becomes part of living, it evokes unmeasurable qualities, and the spirit of its existence takes over." (Lobell and Kahn, 2008: 48)

However, the value of observing geometric relationships as a method of investigating context is the subject of some debate. George Hersey has suggested that analysing architectural geometries can expose hidden associations:

> "the analysis of geometrically constructed plans and elevations can reveal connections between architectures that, from a strictly stylistic viewpoint, seem unrelated. In other words, geometry brings together things that up to now have been considered too separately." (Hersey, 2000: 223)

Presumably, this refers to revealing connections the architect has intentionally applied through their approach to geometry, but that are not immediately apparent in the resulting built form. Conversely, however, Hersey also suggested that it is futile to study geometric approaches in order to gain greater insight into architectural intent:

> "To make geometric analyses by trying to get inside the head of a long-departed architect is folly… the shapes an architect

chooses are matters of fact; how he arrived at them is a matter of opinion." (Hersey, 2000: 14)

This argument is countered by Peg Rawes' interpretation of Immanuel Kant's "Critique of Pure Reason". Kant has described geometry as an "*intermediary* knowledge" — which exists as both "unextended intuition" and also in our spatial and temporal "sense intuitions" (Rawes, 2008: 11). Rawes therefore proposes that "*a priori* forms of geometric intuition may give rise to mathematical *and* aesthetic modes of expression", and that as a result, "scientific geometry is reconnected to aesthetic conditions of production" (Rawes, 2008: 5). Therefore, Rawes seems to imply that our experience of geometry can help bridge the "numerical principles" and the "aesthetic effects" described by Sterken (Sterken, 2007: 31) when considering the relationship between architecture and music.

Ernst Weber has provided a valuable contribution to this thinking with direct reference to architecture and music, observing the human ability to perceive relative proportions of both structural and sonic forms without explicit quantification of the subject matter:

> "The ability to grasp relationships between total quantities without measuring these quantities with a small unit, and without knowing the absolute difference between the two, is an exceptionally interesting psychological phenomenon. In music we can perceive tonal relationships without knowing the number of vibrations involved: in architecture we can conceive of spatial relationships without having to measure them in inches". (Weber et al., 1996: 212)

In considering these contrasting perspectives, this research takes the position that architectural geometry provides a similar level of insight as a musical score (written notation, graphic, instruction, etc.) or open

source code in digital art practice. Whilst viewing any of them cannot give a full explanation of either the creative intent or the experience of the finished work, it is often the only tangible conduit connecting the two, and a critical influence in the creative process. As Victoria Bradbury has stated:

> "underlying programming code is viewed as inseparable from the meaning of an artwork" (Bradbury, 2015: 15)

Our quantitative toolsets for analysing spatial and temporal contexts in this manner may lack the capacity for nuance, but in terms of this research, they at least can be understood in similar terms:

> "Just as Cartesian geometry is a reductive way of understanding space, so too is the measure of time, the clock, a reductive comprehension." (Elden, 2013: 4)

However, returning to Louis Kahn's notion that the architect must go "through the measurable" (Lobell and Kahn, 2008: 48) in order to realise their ideas, the same is not true of the inhabitant of a building, or a casual observer. In essence, for pragmatic reasons an architect's relationship with a building may necessitate the application of "numerical principles" (Sterken, 2007: 31), but an occupant or passer-by can experience the same architectural context in purely emotive terms, based on the architecture's "aesthetic effects" (Sterken, 2007: 31).

This therefore raises potential questions concerning whether creative works derived from "numerical principles" might be more suited to exploring the architect's own relationship with an architectural context, whilst an interpretation of "aesthetic effects" might be more appropriate when exploring the occupier's experience of architectural space. However, this separation would merely serve to perpetuate the division

of roles defined by an over-simplistic producer-consumer interpretation of architecture, and subsequently do not feature in the findings.

Mindful of this issue, this research assumes Jonathan Hill's less hierarchical perspective that "architecture is the gap between building and using" (Hill, 1998b: 141) and that "As architecture is designed and experienced, the user has as creative a role as the architect" (Hill, 1998b: 140).

2 Architecture and music

The ambition for the following general contextual review is not to provide a comprehensive list of projects and practitioners that have sought to combine elements of architectural, sonic and artistic practice. Rather, it aims to give an overview of the manner in which the connections between architecture and sound/music have developed over time, providing specific examples in order to understand where my own practical research projects fit within the evolution of the field.

2.1 Historical context

2.1.1 Antiquity

To understand current practice, it is helpful to consider numerical and aesthetic approaches to bridging architecture and music within the historical debate concerning harmonic theory, as demonstrated by this quote from musicologist Alfred Lang:

> "The Greeks already had two schools of musical thought: Aristoxenus was a pragmatist, interested in music and in art, whereas the Pythagoreans considered it a science, a department of mathematics. The Aristoxian school relied on the musical ear, the Pythagorean on numbers.' (Lang et al., 1997: 14)

Whilst Aristoxenus didn't reject Pythagorean principles and mathematics in their entirety, he considered them irrelevant to his thinking on harmonics due to the fact that "we do not perceive musical sound as ratios or relative speed…. even if they are true of unperceived physical events" (Gibson, 2005: 16). However, it is important to note that despite Aristoxenus' desire to move away from mathematical calculations, towards a depiction of music "as it was heard" (Gibson,

2005: 15), his approach was still embedded in (or at least, articulated through) a quantifiable geometric framework (ibid.).

The impact of Aristoxenus' work on harmonics was profound, described by Sophie Gibson as the birth of musicology (Gibson, 2005: 6). However its reach went beyond music, and significantly for this research, was credited at various points in Vitruvius' hugely influential "Ten Books on Architecture" in the sections on 'Harmonics' and 'Sound Vessels'. This influence was undoubtedly related to Vitruvius' belief that architects should have at least a basic understanding of music, although his focus on mathematical theory would perhaps have been at odds with Aristoxenus' methods. Vitruvius stated that:

> "Music, also, the architect ought to understand, so that he may have knowledge of the canonical and mathematical theory, and besides be able to tune ballistae, catapultae, and scorpiones to the proper key" (Vitruvius Pollio and Morgan, 1960: 8)

The significance of Aristoxenus' "Harmonics" is not that he rejects mathematical tools to describe his theories, but that he rejects "arithmetical definition of music space" (Gibson, 2005: 22), in favour of an approach based on real world observations and experience.

Therefore, returning to Sven Sterken's observation of the connections between architecture and sound/music typically falling into either "numerical principles" or "aesthetic effects", this separation can be understood in the context of a two-thousand year debate concerning the Pythagorean / Aristoxian schools of thought on harmonics. The detail of this particular debate naturally falls far beyond the scope of this research, but hopefully this overview sheds some light on early theories that are still relevant in contemporary practice.

Composer and acoustic ecologist Murray Schafer has provided another useful historical perspective on mathematical and emotional approaches to creative practice. Related closely to Nietzsche's "The Birth of Tragedy" (and also Descarte's opinions on mind-body duality), Schafer suggests all music theory can be traced back to the Greek mythological duality of Apollo and Dionysus:

> "In the first of these myths music arises as a subjective emotion; in the second it arises with the discovery of sonic properties of the materials of the universe. These are the cornerstones on which all subsequent theories of music are founded… In the Dionysian myth, music is conceived as internal sound breaking forth from the human breast; in the Apollonion it is external sound, God-sent to remind us of the harmony of the universe. In the Apollonian view music is exact, serene, mathematical, associated with transcendental visions of Utopia and the Harmony of the Spheres… Its methods of exposition are number theories… In the Dionysian view music is irrational and subjective. It employs expressive devices: tempo fluctuations, dynamic shadings, tonal colorings. It is the music of the operatic stage… Above all, it is the musical expression of the romantic artist" (Schafer, 1993: 6)

Interestingly, Nietzche has also described a connection between music and architecture, but only through what he considered the mathematical (Apolline) means, not through subjective, emotional (Dionysian) experience. He draws a specific distinction between the "Apolline art of the sculptor and the non-visual, Dionysiac art of music" (Nietzsche and Tanner, 1993: 14), suggesting that "Dionysiac music in particular induced feelings of awe and terror" (Nietzsche and Tanner, 1993: 20), whilst music could only be an Apolline art "in terms of its rhythm" (Nietzsche and Tanner, 1993: 20) — i.e. something that is evidently quantifiable and measurable in time:

"The music of Apollo was Doric architecture transmuted into sounds… Care was taken to ensure that the one element held to be non-Apolline was excluded, the very element of which Dionysiac music consisted – the overwhelming power of sound, the unified flow of melody and the utterly incomparable world of harmony" (Nietzsche and Tanner, 1993: 20-21)

The observation of numerical associations between architecture and music can be interpreted chronologically as a historical record of metaphysics, documenting a specific strand of human attempts to understand the Universe. Pythagorean theory didn't simply deconstruct musical harmony in terms of its underlying numerical ratios, but Pythagoreanism as a religious brotherhood elevated number theory to a mystical level, positing that "reality, including music and astronomy, is, at its deepest level, mathematical in nature" (Thesleff, no date). The effects of this perceived association between number, nature, and spirituality can be seen throughout the interrelated history of architecture and music.

Theologist Saint Augustine of Hippo has been credited with the increased acceptance of these Pythagorean principles across European Christian culture during the Medieval period through his treatise "De Musica", written in the late 4th Century (Morris, 1995). Morris describes how Augustine made direct links between mathematical interpretations of architecture and music, and a heightened spirituality:

"In an attempt to anchor both music and architecture in metaphysical reality he called for the direct transference of harmonic proportions to sacred architecture. For him the contemplation of geometry in music and architecture was seen to play an "anagogical" function: one leading the mind from the world of appearances to an understanding of the Divine." (Morris, 1995: 67-68)

Similarly, in their "Treatises of the Pious Brethren" (Walker, 2011), 10th century Muslim philosophers Ikhwãn al-safã (also Eḵwān al-Ṣafāʾ — the Brethren of Sincerity / Purity) also wrote of the connections between mathematics, architecture, music, and art, as well as astronomy and other aspects of religion, science and medicine (Elrawi, 2014: 1).

Despite European and Arabic cultures developing separate approaches to musical theory that each employ different scales and modes, numerical observations concerning the underlying physics of sound and music can nevertheless be seen as having influenced architectural thinking across cultures for many hundreds of years.

2.1.2 The Renaissance

> "The mappings between [Renaissance] architecture and music involved the preservation of ratios, rather than numbers or actual dimensions. Musical ratios pertain to harmonies that Renaissance architects attempted to relate to the whole-number proportioning of rooms and the dimensions of facades." (Coyne, 2011: 137)

During the European Renaissance period, both Leon Battista Alberti (1404-1472) and Andrea Palladio (1508-1580) were heavily influenced by their studies of classical architecture and the writings of Vitruvius, and each proposed systems for proportioning architectural works which are said relate to musical intervals (Graefe, 2014: 144). However, there are inconsistent interpretations of how this association was applied. For example, Mitrović and Djordević suggest that as well as squares (1:1 ratio) and circles, Palladio proposed room proportions based on rectangles with "length/width ratio of 4/3, √2/1, 3/2, 5/3 or 2/1" (Mitrović and Djordjević, 1990: 1). Reading these as ratios (4:3, √2:1 etc.), there is indeed a connection between the whole number ratios (i.e. all excluding √2:1) and frequency ratios in Western musical intervals:

1:1 – unison
4:3 – perfect fourth
3:2 – perfect fifth
5:3 – major sixth
2:1 – octave

("List of intervals in 5-limit just intonation," 2018)

However, in Rasmussen's description of Palladio's Villa Foscari, he references only three of these ratios, 3:4, 4:4 (1:1 — unison), and 4:6 (2:3), selectively stating that these simple ratios "are found in music harmony" (Rasmussen, 1964: 110-111). Yvonne Graefe also suggests that "Palladio also put an emphasis on the proportions 4:5, 5:6 and 3:5" (Graefe, 2014: 144).

Similarly, the slightly later French architect and theorist Jacques-François Blondel (1705-1774) worked closely with the musician René Ouvrard in developing his own system of architectural proportions based on eight musical ratios in his "Cours d'Architecture", which George Hersey describes as "musico-architectural landmark" (Hersey, 2000: 38). Perhaps unsurprisingly, these consisted of 1:1 (unison), 2:1 (octave), 6:5 (minor third), 5:4 (major third), 4:3 (fourth), 3:2 (fifth), 8:5 (minor sixth), and 5:3 (major sixth) (Hersey, 2000: 38).

It is therefore important to acknowledge that a great many whole number ratios are present in acoustic and music theory, which can be readily and conveniently applied in architectural form. Those ratios put forward by Palladio and others (and analysts of their work) represent only a small proportion of the recognised ratios in Western musical scales alone. This raises the question as to whether the results create any aesthetic connection, or merely a convenient, numerical association. Subjectively, Rasmussen suggests that in Palladio's work at least, they do:

"But, you may ask, does the visitor actually experience these proportions? The answer is yes – not the exact measurements but the fundamental idea behind them. You receive an impression of a noble, firmly integrated composition in which each room presents an ideal form within a greater whole. You also feel that the rooms are related in size. Nothing is trivial – all is great and whole." (Rasmussen, 1964: 111)

2.1.3 The Temple of Music

Another interesting contributor to the field was Robert Fludd (1574-1637), whose interests bridged science, music, mathematics, and the occult. As Peter Haugh explains:

"For Fludd, the relationships between figures or numbers (that is, the musical intervals and rhythms) were essential for understanding the composition of the universe, and hence music" (Fludd and Hauge, 2011: 4)

In his book "Utriusque Cosmi" (c. 1610), Fludd depicted his interpretation of musical theory through illustrated architectural forms. Fludd's "Temple of Music" not only represents numerical relationships in music, but places the mathematics directly within a mythological context, depicting Pythagoras alongside Apollo, and also Saturn (the guardian of time, or rhythm), but with no reference to Dionyses:

"… Apollo, the leader of the Muses and guardian of melody, is placed with his lyre; Saturn (guardian of rhythm) appears with his scythe above a clock measuring time; in the middle tower's cellar Pythagoras is seen in the doorway listening to blacksmiths Jubal and sons" (Fludd and Hauge, 2011: 7)

In describing his interpretation of the relationship between music and numbers, Fludd presents the sonic medium in both spatial and temporal terms. This is significant in the context of this research, which assumes the viewpoint that experience of both architecture and music are each necessarily spatial and temporal, and Fludd therefore provides an early example of how mathematics has been employed as a creative tool for bridging these two dimensions. In the "Temple of Music" (c.1610), Fludd said:

> "[Music] is either *positional…* or *durational…* It is therefore evident that harmonic music is a discerning of measurement." (Fludd and Hauge, 2011: 43)

In terms of Fludd's legacy, his words bear a striking similarity to those written by Le Corbusier over 300 years later (c.1948), when describing his approach to architecture in terms of musical harmony:

> "Music, like architecture, is time and space. Music and architecture alike are a matter of measure." (Le Corbusier, 1961: 29)

More immediately within the 17th century, Fludd's work was already inspiring Athanasius Kircher (1602-1680) (Devlin, 2002), whose book "Musurgia Universalis" was in turn highly influential on the likes of Bach and Beethoven (Glassie, 2012: 124). Like Fludd, Kircher visualised his musicological theories with detailed illustrations, including a mechanical organ that incorporates the Pythagorean blacksmiths as percussive automata. But perhaps most relevant to this study is the plate that depicts a series of horns transmitting sound through the cross-section of a building, and demonstrating Kircher's thoughts on what he called "tone architecture" (Glassie, 2012: 119), observing the ways in which different structures and surfaces can be tailored to manipulate our acoustic and architectural experience.

However, the immediate popularity of Kircher's work was relatively short-lived against the backdrop of the Enlightenment. Despite developing a fascinating numerical (quantitative) "music-computing" tool for aleatoric (chance) music composition, as well as a strong belief that "music's great purpose was to echo and evoke human emotions" (Glassie, 2012: 123-4) (i.e. qualitative), Kircher's work across disciplines was fundamentally spiritual – a "grounds for praise of God" (Glassie, 2012: 125). As a consequence of this, his tendency towards a mystical, numerological approach was seen as somewhat at odds with the evolution of more scientific approaches to mathematics such as Cartesian geometry (Glassie, 2012: 242), to the extent that Kircher's later work was dismissed as "grand quackery" by one contemporary (Glassie, 2012: 233).

2.1.4 Frozen Music

Despite this, Kircher's influence should not be overlooked, but the nature of this change in critical thinking across disciplines was significant, and resulted in one of this topic's ubiquitous tropes. Friedrich von Schelling's description of architecture as "frozen music" in his 1802 "Philosophie der Kunst" (a phrase that has also been attributed to his associate Johann Van Der Goethe, among others) included an oft-overlooked suffix, which Hersey describes as claiming that:

> "The thing that "freezes" music into architecture… is geometry."
> (Hersey, 2000: 27)

This is confirmed in Schelling's Philosophy of Art, in which he states:

> "architecture, as the music of sculpture, necessarily follows arithmetic relations, since, however, it is the music in space, as it were the frozen music, so these ratios are both geometric relationships… Architecture therefore necessarily forms

according to arithmetical or, because it is music in space, to geometric relationships. (Schelling, 1859: 576)

On first reading, this description appears to echo elements of Leibniz's description of music as "a hidden arithmetic exercise of the soul, which it does not know that it is counting" (Nierhaus, 2010: 28). However, Schelling also explains that this geometric connection between disciplines only relates to the physical form or structure of the work, and that in order to understand the underlying artistic statement, viewers must look beyond a quantitative interpretation of the art object:

> "We must look beyond form in order to gain an intelligible, living, and true perception of it. Contemplate the most beautiful forms, and what remains when you have denied in them the effective principle? Nothing but mere abstract qualities, such as extension and the relations of space" (Schelling, 1845: 7)

This notion is reiterated here:

> "But architecture is a form of sculpture, and if it is music, it is concrete music. It cannot represent the universe merely by the form, it must represent it in essence and form at the same time." (Schelling, 1859: 577)

In discussing Schelling's "System of Transcendental Idealism", Fackenheim describes Schelling's perception of artistic practice through a series of dualisms, stating that "Artistic creation is at once conscious and unconscious, finite and infinite, unfree and free" (Fackenheim and Burbidge, 1996: 66), each of which can be understood in relation to the division Schelling establishes between the objective and the subjective:

> "Architecture, in order to be beautiful art, must present the expediency which is in it as an objective purposefulness, i.e. as

the objective identity of the concept and the thing, of the subjective and the objective." (Schelling, 1859: 580)

Therefore, behind Schelling's seemingly quantitative (geometric) trope describing architecture as frozen music, there is also the expectation of a qualitative interpretation in order to understand the work as a whole. This provides some useful context for Sven Sterken's observation that connections between architecture and music have been based either on "the same numerical principles" or through "aesthetic effects and its immersive power" (Sterken, 2007: 31).

We also see Schelling's ideas echoed in Louis Kahn's belief that the poetic architect must move freely between the measurable and the unmeasurable:

"The poet is one who starts from the seat of the unmeasurable and travels towards the measurable, but who keeps the force of the unmeasurable with him at all times" (Lobell and Kahn, 2008: 14)

This ambition aligns with Schelling's philosophy of art, as he believed "All fine art is the imagination of the infinite into the finite, of the ideal into the real" (Schelling, 1859: 629), specifically noting that poetry is "the unity of the infinite and finite" (Schelling, 1859: 456). One definition of "infinite" is "impossible to measure or calculate" (Definition of 'Infinite' 2019), in contrast to the term "finite", which can be defined in purely quantitative terms: "completely determinable in theory or in fact by counting, measurement, or thought" (Definition of 'Finite' 2019).

2.2 Early 20th Century

The proliferation of interdisciplinary creative practice throughout the 20th Century (and the availability of associated documentation) resulted in a

huge range of contributions to this field, far beyond the scope of this research. As such, the focus here is on a small number of key practitioners whose work articulates the evolving role of numerical and aesthetic (quantitative and qualitative) approaches to articulating the relationship between sonic and plastic art forms.

2.2.1 Bauhaus

Perhaps unsurprisingly, the Bauhaus was home to a number of influential practitioners in this area during the first third of the 20th Century, the artist Paul Klee being one notable example of many. Besides his visual practice, Klee also played violin (Grant, 2005: 37), and his work and teaching made direct connections between visual and sonic works, as Vergo describes:

> "…Klee went beyond both Itten or Feininger in seeking a precise pictorial equivalent for musical forms including the strict procedures of fugue. His painting *Fugue in Red* of 1921 exhibits several easily identified "motifs" which it is tempting to compare to the subjects and counter-subjects of a fugue composition." (Vergo, 2011: 15)

Klee's approach to visual art was influenced by the mathematical exactness of music theory and science (Grant, 2005: 37), but not to the exclusion of aesthetic judgement. In Klee's own words, "intuition and exact research must go hand in hand, the one tempering and thus advancing the course of the other" (Grant, 2005: 38). As part of his teaching in 1921-22, Klee created a visual representation of Bach's "Sonata No. 6 in G", a form of graphic score depicting what he called "visual rhythm" (Vergo, 2011: 16).

In light of this teaching methodology, it is perhaps no coincidence that one of his students, the Hungarian painter and musician Henrik

Neugeboren (later also known as Henri Nouveau), designed a three-dimensional sculptural work based on a phrase from the 8th fugue of Bach's "The Well Tempered Clavier" (Neugeboren, 1929: 16). However, it appears Neugeboren's work was purely quantitative in its approach to translating between art forms, asserting that is was in no way "a personal interpretation in an appropriate mood, but rather a scientifically exact translation into another system" (Neugeboren, 1929: 16). It is interesting to note that in creating the sculptural model, Neugeboren worked with Konrad Püschel, a student of architect László Moholy-Nagy (Vergo, 2011: 16), the Bauhaus tutor who composer and artist John Cage later cited as a key influence on his approach to the relationship between architecture and music (Joseph, 1997: 86-87), alongside the work of Mies Van Der Rohe, who was the Bauhaus director from 1930 to 1933 (*Ludwig Mies van der Rohe*, no date.).

2.2.2 Serialism

Another key contribution to this field in the early 20th century was composer Arnold Schoenberg's twelve-tone technique, and the role it played in the wider development of serialism across the arts.

Serialism is a process-based creative methodology that is "based on a special relationship between individuality (uniqueness) and similarity" (Bandur, 2001: 7). The approach is summarised by Sandra Louise Kaji-O'Grady as follows:

> "rules are given at the outset of making a work of art to regulate the permutation, combination, frequency, repetition and internal relations of multiple identifiable elements". (Kaji-O'Grady, 2001: 1)

Schoenberg's influential compositional technique rejected traditional approaches to harmony, instead developing a system for atonal

composition that theoretically gives equal representation to each of the twelve notes in the "row", treating each individually and without hierarchy.

Within music composition, the influence of Schoenberg's method had immediate effect though the students of the Second Viennese School (including Alban Berg, Anton Webern and Olivier Messiaen), and later with Karlheinz Stockhausen, and Pierre Boulez, who extended the technique to encompass not only pitch, but also rhythm, timbre, dynamics and instrumentation (Kaji-O'Grady, 2001: 10), with Kaji-O'Grady describing his work as existing "in the intersection between systematic order and the unforeseen" (Kaji-O'Grady, 2001: 12).

But the reach of serialism went far beyond its mathematical compositional roots, employed as an interdisciplinary device "which enables (and needs) all arts to be integrated into one creative concept" (Bandur, 2001: 6). As a result, serialism has also been adopted by poets, visual artists, architects and even philosophers such as Derrida and Deleuze (Kaji-O'Grady, 2001: 4).

For example, parallels have been drawn between the serialism of composer Pierre Boulez and the drawing systems employed by Sol LeWitt in his Drawings Series I, II, and III (Gieskes, 2004: 26). Indeed LeWitt himself compared his working process to that of an architect or composer, pointing out that, "The composer doesn't play any instruments… The architect doesn't go off with a shovel and dig his foundations and lay every brick" (quoted in Gieskes, 2004: 27). This raises the interesting question as to what constitutes the artwork, and therefore, who is the artist. Is the artwork the underlying concept, or the creative process? Is it the set of instructions, score, or architectural drawing? Or is the artwork the "completed" work as presented, different each time, and therefore shaped by the painters, musicians or builders who interpret and realise those instructions?

In terms of the legacy of serialism, its methods have subsequently also been applied by architects such as Bernard Tschumi in his Parc de la Villette (Kaji-O'Grady, 2001: 215), and more recently Daniel Libeskind, whose design for the 2001 Jewish Museum in Berlin took inspiration directly from Schoenberg's serial composition Moses und Aron (Joseph, 1997: 81; Quek, 2008: 48),

2.3 Mid-20th Century

The mid-20th century saw the emergence of a plethora of widely recognised Western architects, composers, and artists continuing to explore working methods across the disciplines, both independently and in collaboration.

Divergent perspectives on matters such as aleatoric processes reflected a changing landscape in terms of how practitioners were articulating and interrogating musical and architectural space. In addition to this, access to new technologies afforded artists the opportunity to devise alternative sonic interventions in architectural space, and create aesthetic sonic experiences in direct response to the acoustics of any given architectural space.

2.3.1 Iannis Xenakis

In observing numerical associations between architecture and music during this period, it is difficult to overlook the contribution of architect, engineer, composer, mathematician, and Greek revolutionary, Iannis Xenakis. The connections between his architectural and compositional work are so widely recognised in this sphere, that even where his approach is beyond the scope of a piece of research, his omission can still be referenced as a "notable absence" (Schrimshaw, 2011: 11).

Some of Xenakis' most widely recognised work came into existence during his time working for the architect Le Corbusier. In 1948, Corbusier had published his book "Le Modulor" (Le Corbusier, 1961), a design manifesto based on an interpretation of the human form, divided up using the golden ratio (1:0.618…). Le Corbusier's description of this so-called "universal harmonious measure" (Le Corbusier, 1961: 177) is peppered with references to music and harmony, but always underpinned with a basis in mathematics:

> "More than these thirty years past, the sap of mathematics has flown through the veins of my work, both as an architect and painter; for music is always present within me." (Le Corbusier, 1961: 129)

Le Corbusier's approach is discussed in greater detail later (see the Scale section, 5.1.4), but it is understandable that his approach to architecture, music, and mathematics found common ground with polymath Xenakis.

Brandon Labelle has described Xenakis' compositional practice as "inherently architectural and mathematical in character" (LaBelle, 2006: 190), which is entirely in-keeping with Xenakis' own acceptance of Pythagorean principles:

> "the Pythagorean concept of numbers affirmed that things are numbers, or that all things are furnished with numbers, or that things are similar to numbers… all intellectual activity, including the arts, is actually immersed in the world of numbers… We are all Pythagoreans." (Xenakis and Kanach, 1992: 202)

This is not to say that Xenakis was averse to the concept of art's transcendent qualities, describing art and music as having a "fundamental function" to "catalyse the sublimation", existing beyond

"objects, emotions, or sensations", and suggesting that "art can lead to realms that religion still occupies for some people" (Xenakis and Kanach, 1992: 1). Nevertheless, his overarching approach to practice is captured by the subtitle of his book (first published 1955), "Formalized Music: Thought and mathematics in composition" (Xenakis and Kanach, 1992) – the pages of which are adorned with numerous mathematical formulae describing his working process.

Xenakis was not, however, a fan of serialism. He described how its exponents "walk on with ears shut and proclaim a truth greater than the others" (Xenakis and Kanach, 1992: 5). Where Pierre Boulez had seen serialism as a creative tool with the capacity to create "unforeseen" results (Kaji-O'Grady, 2001: 12), Xenakis simply felt that "the works themselves produced an auditory and ideological nonsense" (Xenakis and Kanach, 1992: 8) – and somewhat ironically, also criticises them for their "enormous complexity" (Xenakis and Kanach, 1992: 8). Perhaps unsurprisingly, his solution to this deterministic "crisis of serial music" (Xenakis and Kanach, 1992: 8) involved yet more mathematics. The result was "Stochastic Music", in which Xenakis introduced scientific laws of statistical probability as a compositional device (Xenakis and Kanach, 1992: 8), which he used in works such as "Pithoprakta" (Xenakis and Kanach, 1992: 19).

Beyond Xenakis' contribution of "Stochastic Music", his mathematical approach to interdisciplinary practice, or meta-art, is perhaps best encapsulated by his 1955 composition "Metastasis", and the architectural form of the 1958 Philips Pavilion he designed whilst working for Le Corbusier. Xenakis claims the creative intent for both was "the question of whether it is possible to get from one point to another without breaking continuity" (quoted in Varga 1996: 24, cited LaBelle, 2006: 187), which was realised mathematically as musical glissandi via the graphic score of "Metastasis", and also architecturally

as ruled surfaces of the sweeping hyperbolic paraboloid concrete structure of the iconic Philips Pavilion.

Xenakis' mathematical approach to art, music, and architecture was ideally suited to emerging digital tools and techniques. Consequently, through the research centre he founded in Paris (CEMAMu), Xenakis developed an early graphical interface for computer music composition and performance, in which the user draws "arcs" with an electro-magnetic pen on a graphic table (*Présentation de l'UPIC · Centre Iannis Xenakis, no date*). Each drawn arc represents a simple graphic score, which is then interpreted and synthesised by the computer, with the X and Y axes controlling the time and pitch (frequency) parameters of the sound that is produced. Whilst the UPIC system wasn't widely used as a compositional tool, it's legacy is ongoing, having inspired the development of similar modern software tools such as HighC (Baudel, 2008) and IanniX (*What is IanniX? | IanniX*, no date).

Beyond his own body of work, Xenakis' legacy is evidenced by both his influence in the development of these creative tools, and by those inspired by his meticulous mathematical approach to interdisciplinary practice. One example of this is the "Xenakis-Emulator" created by architect and artist Mark Kammerbauer in collaboration with Alexadra Schnellbögl in 1999 (Kammerbauer, 1999). This audiovisual project (presented as single channel digital video) interprets Xenakis' window arrangement for Le Corbusier's La Tourette monastery as a graphic score. Kammerbauer and Schnellbögl take Xenakis' "polyrhythmic study of light and shade" (Sterken, 2007: 37), and quantitatively translate the spatial proportions of La Tourette's undulating openings into a temporal series of sonic events.

2.3.2 John Cage

Le Corbusier's approach to the "Modulor" was entirely at odds with the philosophy of composer and artist John Cage. Responding to Corbusier's assertion that his proportioning system "must be proclaimed by law", Cage wrote in "Rhythm Etc." "Art this is called. Its shape is that of tyranny." (Joseph, 1997: 83). "Le Modulor" also represented an attempt to reassert traditional approaches to harmony, at a time when composers of new music, such as Cage, were striving to free themselves of such constraints.

Schoenberg's compositional method also failed to convince Cage, who said that, "The twelve-tone row offers bricks but no plan" (John Cage, quoted in Joseph, 1997: 96).

Nevertheless, it is interesting to consider Cage's work in relation to the evolution of serial thinking more broadly, once again considering Pierre Boulez's approach to serialism in creating "unforeseen" results. Where Xenakis felt the need to consolidate this notion through the application of mathematical stochastic laws, Cage's perspective on aleatoric processes in composition is perhaps best understood by his phrase "Sound production may be understood as simply opening doors" (Fowler, 2012: 163). Echoing Boulez, Cage also described an experimental act as "simply an action the outcome of which is not foreseen" (Joseph, 1997: 74).

Whilst both Cage and Xenakis were working with aspects of indeterminate practice, it is interesting to note the degree of disparity in their perception of the subject. For example, without directly naming Cage, Xenakis described the "so-called aleatory music" of the era as "an abuse of language" (Xenakis and Kanach, 1992: 180) that was simply "the 'improvised' music our grandfathers knew" (Xenakis and Kanach, 1992: 181).

However, both Cage's reasoning for, and application of, aleatoric processes undeniably set his work apart from his predecessors, not only in sonic work, but also in poetry and visual art. Cage was actively trying to limit the "controlling force of ego" (Joseph, 1997: 11), which Alvim describes as a "rejection of the authoritarian control of the composer" (Alvim, 2018: 58). Cage explained in an interview how "instead of coming from my likes and dislikes, [answers] come from chance operations" (Montague, 1985: 212). In doing this, Cage made extensive use of the ancient Chinese text "I Ching" (Book of Changes), although interestingly, it has been suggested that his interpretation of the text is actually more closely aligned with serialism, than with the "I Ching" philosophy (Jensen, 2009: 98).

Beyond the reasoning for his use of aleatoric processes, it is the manner in which Cage represented these chance events in his work that constituted a major shift in the field. Cage himself recognised his "silent" piece "4'33"" as his most important work (Montague, 1985: 213), which "consisted solely of an empty time-structure of three silent movements through which any sounds emanating from the environment could flow" (Joseph, 1997: 85). Consequently, the performed work isn't silent at all, but a three-dimensional collage of sounds whose tone, timbre and timing are beyond the control of the composer, who has framed them within the duration of the piece. Where Boulez and Xenakis used serial and stochastic systems to dictate the notes in a piece, for Cage, the chance events constituted the piece itself, his silences allowing space for the sounds that he described as simply "not notated" (Joseph, 1997: 85). Whilst this approach has been criticised by some observers as a means of abdicating artistic responsibility, Jensen refutes this accusation based on the manner in which Cage carefully shaped the parameters of his compositions:

"Cage sought a balance between the rational and the irrational
by allowing random events to function within the context of a
controlled system" (Jensen, 2009: 97)

Returning to the connections between architecture and music, although
Cage forcefully distanced his own work from the quantitative methods of
Le Corbusier, he was not averse to architectural analogies in general.
Specifically, Cage observed a similarity between the aesthetic role of
architectural glass and his use of compositional "silence", each
providing their respective medium with an openness that catalyses an
interpenetration between the work and its surrounding environment. To
articulate this point Cage referenced the work of two leading figures
from the Bauhaus, describing how the glass in László Moholy-Nagy's
buildings allowed them to "dematerialize" (Joseph, 1997: 88), and how
the type of openness he created by "opening the doors of the music to
the sounds that happen to be in the environment" was equivalent to the
aesthetic experience produced through Mies van der Rohe's extensive
use of glass in his architecture (Joseph, 1997: 85).

The significant legacy of Cage's work is evident not only in the
continued appetite for performances and exhibitions of his sonic and
visual works, but also in the work of numerous contemporary
composers, artists (e.g. Nam June Paik), and architects who have been
influenced by his creative process. One notable example of this is Yago
Conde, who employed Cagean indeterminacy as an architectural
method in his 1988 concept for a fountain in Barcelona's Olympic
Village – which was based on Cage's "Fontana Mix". Interestingly,
Michael Fowler suggests that:

"Conde is concerned not with the act of translating a spatial or
sensorial experience from music into built form, or generating
architecture from mathematical principles, but with using the

potential of a spatial incompleteness as a program for driving architectural design decisions" (Fowler, 2012b: 35)

In saying this, Fowler implies that this approach to indeterminacy moves away from aesthetic or numerical methods so often associated with the relationship between architecture and music, towards a focus on "incompleteness" – concerned not with the decisions that have been made, but on those that have been left undecided.

2.3.3 Aural architecture

"Can architecture be heard? Most people would probably say that as architecture does not produce a sound, it cannot be heard. But neither does it radiate light and yet it can be seen. We see the light it reflects and thereby gain an impression of form and material. In the same way we hear the sounds it reflects and they, too, give us an impression of form and material." (Rasmussen, 1964: 224)

Our experience of sound is unavoidably shaped by our surroundings, and as such is greatly influenced by the built environment. As Brandon Labelle explains, "Sound is intrinsically and unignorably relational" and that "sound and space in particular have a dynamic relationship" (LaBelle, 2006: ix). Diogo Alvim describes music as being "dependent on space and thus intensely connected to architecture" (Alvim, 2018: 54).

Earlier in the 20th century, the influential architect Frank Lloyd Wright had been calling for a "subjective use of acoustics that did not follow his contemporaries' quantitative and empirical approach" (von Fischer and Touloumi, 2018: 877), and the mid-20th Century presented new opportunities for practitioners to explore the connection between sound

and space — in no small part due to the emergence and availability of new electronic technologies.

The term "aural architecture" has been defined by Blesser and Salter as simply referring to "the properties of a space that can be experienced by listening" (Blesser and Salter, 2009: 3), and therefore, the aural architect is:

> "someone who selects specific aural attributes of a space based on what is desirable in a particular cultural framework. With skill and knowledge, an aural architect can create a space that induces such feelings as exhilaration, contemplative tranquillity, heightened arousal, or a harmonious and mystical connection to the cosmos." (Blesser and Salter, 2009: 3)

Based on this definition, this period saw some highly influential artistic contributions to the field, including notable works by La Monte Young and Marian Zazeela, and Alvin Lucier, each of which articulate the physical relationship between sound and architectural space in their own way.

2.3.4 La Monte Young and Marian Zazeela

Young and Zazeela define their long-running "Dream House" installation as a "sound and light environment", and "a time installation measured by a setting of continuous frequencies in sound and light" (*Dream House*, no date). Charles Curtis has described the "Dream House" as follows:

> "Hanging mobiles and coloured lights project coloured shadows that move slowly in response to the motions of the air. Arrays of continuous sine waves – as many as 45 at once – radiate such close patterns of standing waves that even minute motions on

the part of a listener reveal new frequencies audible at that specific location." (Curtis, 2009: 108)

The acoustic experience of visiting a "Dream House" is created by the physical interaction between the synthesised tones and their environment, and each visitor's sonic journey will be unique despite the unchanging nature of the sounds being generated. This immersive aesthetic could be interpreted as a perfect example of a qualitative creative approach to connecting architecture and sound, with the focus on:

> "exploring space, one's own relation to it and the psychoacoustic occurrences within one's own auditory system... From Young's point of view, the search was still for 'self-reflection and a meditative state'" (Glover, 2013: 13)

However, it is interesting to note that, despite original plans to use live musicians, followed by the use of highly stable analogue tone generators (Glover, 2013: 13), the online press release for "Dream House" (March 2019) describes the sonic component (which now uses real time digital synthesis) in purely quantitative terms:

> "Young's sound environment is composed of frequencies tuned to the harmonic series between 288 and 224, utilizing numbers with factors of only 9, or those primes or octave transpositions of smaller primes that fall within this range. The interval 288/256 reduces to a 9/8 interval as does the interval 252/224. Thirty-two frequencies satisfy the above definition, of which seventeen fall within the range of the upper, and fourteen fall within the range of the lower of these two symmetrical 9/8 intervals. Young has arranged these thirty-one frequencies in a unique constellation, symmetrical above and below the thirty-second frequency, the

center harmonic 254 (the prime 127 x 2)." (*Dream House*, no date)

The digital synthesis affords Young a level of forensic numerical control that would have been unachievable in the original 1966 "Dream House" in 1966, so his approach to tuning would arguably have relied more on aesthetic choices, based on the physical interaction of sound and space, and less on the mathematical accuracy provided by digital tools. This serves to underline the complex relationship between qualitative and quantitative aspects of aural architecture throughout the creative process — from concept, through realisation and experience, to communication.

2.3.5 Alvin Lucier

Alvin Lucier has been described by Douglas Kahn as being "for more than four decades, the most important composer of space" (Kahn, 2009: 24), and the reasons for this are perhaps best captured by his most famous work, the 1969 process-based piece "I Am Sitting in a Room".

The looped process that underpins the work begins with Lucier reading a prepared script to tape, which is then played back through a speaker in the room and re-recorded, then the new recording is played back and recorded, and so on. The result of this recording technique is that the acoustic properties of the room become gradually more present with each iteration, finally engulfing the recorded speech with the resonant frequencies contributed by reverberation from the surrounding environment (and albeit to a lesser extent, from the character of the speaker and microphone used to create the piece). Even if the script and delivery were to remain the same, the piece will always result in a unique sonic character, shaped by the space in which it is recorded. Lucier explained that, "Every room has its own melody, hiding there

until it is made audible' (Lucier and Simon, 1980: 37 cited Rogalsky, 2010: 135).

Lucier's recorded speech explains the process for the audience, and anticipates the acoustic effects on his recorded voice. But perhaps most interestingly, it concludes:

> "I regard this activity not so much as a demonstration of a physical fact, but more as a way to smooth out any irregularities my speech might have." (Lucier quoted in Kahn, 2009: 28)

It is interesting conceptually to consider how Lucier, who had a tendency to stammer when talking, observes the capacity for his architectural surroundings to modify, or perhaps homogenise, his speech.

Given this focus, this creative process again could be interpreted as reflecting a wholly qualitative approach. His method doesn't employ classical harmonic ratios or fixed tunings, and unlike in Young and Zazeela's current iteration of the "Dream House", Lucier isn't generating any mathematically derived frequencies to achieve the desired effect.

Nevertheless, the quantifiable aspect of soundwaves was in fact instrumental in shaping Lucier's creative practice, and was central in his approach to developing work that acknowledged the critical relationship between sound and architecture:

> "Thinking of sounds as measurable wavelengths, instead of as high or low musical notes, has changed my whole idea of music from a metaphor to a fact and, in a real way, has connected me to architecture." (Lucier, 1995, cited Kahn, 2009: 28)

Once again, this evidences some of the intricacies involved in creating work that encompasses sound practice and architectural context. Whilst Sterken highlighted the tendency for connections between music and architecture to be either based on "the same numerical principles" or through "aesthetic effects and its immersive power" (Sterken, 2007: 31), some of the most interesting work can be understood as combining both perspectives.

As such, the reality is somewhat more nuanced, and highly subjective. For example, one listener might engage with the immersive effect of "I Am Sitting in a Room" on purely aesthetic terms, whilst another (possibly Iannis Xenakis, for example) might consider the sonic effects in granular terms, each element behaving predictably in a mathematical sense, merely responding to the geometry and materiality of its physical surroundings.

2.4 Contemporary

As can be seen, the evolution of praxis in this field of enquiry has been gradual, often reflecting progress made over the duration of a personal career or collective endeavour. As such the term "contemporary" will be used quite generously to cover a period of decades spanning the late 20th and early 21st century.

In practice-based academic research, various new perspectives have contributed to the debate. These include Diogo Alvim's compositional methodology inspired by an architectural framework consisting of "Material, Site, Drawing, Programme and Use" (Alvim, 2016: 2), and Tomek Smierzchalski's work reframing of the nature of architecture-music translations as either demonstrating "predefined order" or "subsequent order" (Smierzchalski, 2007: 53). This summary will focus on specific examples of practice that demonstrate the approaches that inform the practical work documented later in this thesis.

Within architecture, there is no shortage of examples to demonstrate the manner in which architecture has continued to embrace its relationship with sound and music in recent years, including Yago Conde's application of Cagean indeterminacy for the fountain in Barcelona's Olympic village, Daniel Libeskind's use of Schoenbergian serialism in designing Berlin's Jewish Museum (Joseph, 1997: 81), as well as the architecture of Renzo Piano, Alvar Aalto, and recent contributions from Victoria Meyers (hMa), Flanagan Lawrence, and many others.

However, perhaps the most prominent and consistent voice has been that of Steven Holl, not only through his own architectural practice and writing, but also through the award-winning "Architectonics of Music" studio course, which he first ran in 1986 through Columbia University ("Architectonics of Music wins Architect Magazine's Studio Prize - Steven Holl Architect," 2018).

2.4.1 Steven Holl

Steven Holl's writing on the relationship between music and architecture again demonstrate how inter-related mathematics (geometry) and subjective experience are for the pragmatic requirements of his discipline. His approach could easily be misrepresented by selective quotes, as his writing and research spans a range of issues. Holl's description of spatial experience is helpful in understanding the concepts that underpin his work on music and architecture:

> "PSYCHOLOGICAL SPACE is at the core of spatial experience. It is intertwined with the subjective impression of actual spatial geometry and born in the imagination. The absolute side of rational planning is in contrapuntal relationship with the pathological nature of the human soul. It is in this mix, at its

architectonic conception, that the spatial spirit of a work of architecture is determined." (Holl, 2011: 11)

This description of spatial geometry as a subjective psychological experience seemingly aligns with Peg Rawes' interpretation of Immanuel Kant's philosophy of mathematics. Rawes has explained that "*a priori* forms of geometric intuition may give rise to mathematical *and* aesthetic modes of expression", and that as a result, "scientific geometry is reconnected to aesthetic conditions of production". (Rawes, 2008: 5)

Holl's interest in bridging mathematical and aesthetic perspectives is underlined by his use of a quote from the composer Béla Bartók, suggesting a belief that artistic instinct and the aesthetic experience should take priority over any scientific or mathematical procedures:

> "We are concerned not only with achievements of purely scientific issues, but also those which have a stimulating effect on composers. According to the natural order of things, practice comes before theory." (Holl, 1998: 6)

Nevertheless, it is important to note that Holl has described mathematics as being of "elementary importance" to both art forms (alongside form, rhythm, and proportion) (Holl, 1994: 57), and even articulates his point in the style of a mathematical formula:

$$\frac{\text{Material x sound}}{\text{time}} = \frac{\text{material x light}}{\text{space}}$$

(Holl, 1994: 56)

Significantly though, Holl has also noted the "narrow channels" of "number, rhythm, notation, and proportion" through which analogies

have previously been made between architecture and music (Holl, 1994: 56), and provides a thoughtful and practical way forward:

> "The question would not simply be "how to compare?" but what unmarked routes to investigate and what experiments to perform" (Holl, 1994: 56)

In his architectural practice, Steven Holl has realised a number of built projects that were informed by music in some way. One of these is Daeyang House in Seoul (constructed 2008-12), which took a visual inspiration from composer István Anhalt's 1967 graphic score for his "Symphony of Modules for orchestra and tape" (*Daeyang Gallery and House - Steven Holl Architects*, no date). On the practice website, it is also noted that Holl found the score in a book by John Cage, "Notations" (*Daeyang Gallery and House - Steven Holl Architects*, no date).

For the Stretto House, Holl developed the architectural plan and elevation in response to the musical structure of "Music for Strings, Percussion and Celesta" by the composer Béla Bartók (Holl, 1994: 56), some of whose work was influenced by Schoenberg's approach to serialism (Nordwall, 1967: 267). Holl specifically observed key elements about the composition's quantitative makeup, such as division into four movements, its contrast in "materiality between heavy (percussion) and light (strings)" (Holl, 1994: 57), and a layering that employs the numerical system of the Fibonacci sequence, or golden ratio (Holl, 1994: 58). Nevertheless, he has described the completed works as sharing a common aesthetic experience informed by the layering of musical and architectural components:

> "In both works, the music and the house, you are left with the sense that something remains hidden, that several layers are at work beneath the structure." (Holl, 1994: 58)

The lineage of Holl's approach perhaps becomes most apparent through his Architectonics of Music studio programme. The award-winning 2018 course run with Dimitra Tsachrelia saw students responding architecturally to Varèse's "Poeme Electronique" – the composition created for the multi-channel sound system in Corbusier and Xenakis' 1958 Phillips Pavilion. *(Architectonics of Music wins Architect Magazine's Studio Prize - Steven Holl Architect, 2018*; Risen, 2018). Previous iterations have seen the participants working directly in response to the music of Iannis Xenakis and John Cage among others, again demonstrating the sustained influence of their approaches on current architectural theory and practice.

2.4.2 Pavilions

Parallels with the collaboration between Le Corbusier, Xenakis and Varèse on the Phillips Pavilion can also be drawn with the continued interest in architectural and musical partnerships in more recent pavilion projects.

In one example, Steve Roden was invited to create a score to accompany Siza and de Moura's 2005 Serpentine Pavilion (Lutz, 2014), culminating in a live performance. Roden took a multi-layered approach to his piece, including elements of recordings made during the construction period (including a talk by architect Eduardo Souto de Moura), locally sourced objects and materials, and the placement of contact microphones onto the structure - turning the architecture into an instrument in and of itself (Roden, no date). These methods can be seen to reflect the wider context within which the architectural form was developed. Roden also interpreted the physical structure as a graphic score, translating the transparent panels of the pavilion shell into a multi-coloured visual that matched the colours of the notes on a child's glockenspiel used in the performance (Roden, no date). This process of

architectonic translation therefore took a far more quantitative approach to the relationship between spatial and temporal events.

Another interesting project is the Swiss pavilion created for EXPO 2000 in Hanover by multi award-winning architect Peter Zumthor and composer Daniel Ott, titled "Klangkörper" ("Sound-body"), and Ott's associated sonic work "Klangkörperklang".

In discussing the work based on its written description, Lutz has identified the "numerical relationships" (Lutz, 2005: 73) between the disciplines:

> "Using the language of mathematics as the common
> denominator, numbers found in the building itself establish the
> sonic and temporal parameters for the improvisational musical
> performances occurring within the space." (Lutz, 2005: 73)

However, video documentation of how audiences experienced the work (Moll, 2010) suggests that this rigid mathematical description doesn't capture the fluidity of the aesthetic encounters the space provided, which were no doubt heavily informed by Daniel Ott's extensive work on theatrical productions.

Zumthor described the project as aiming to create a "Gesamtkunstwerk", or "total work or art" (Etherington, 2009; Lutz, 2005: 73) that unified multiple artforms:

> "Dramatic music played by musicians moving around, culinary
> offers, fashion and key words about Switzerland written in light…
> all this was designed to merge with the architecture"
> (Etherington, 2009)

And perhaps it is the peripatetic actions of the live performers that allows the relationship between the architectural and musical forms to go beyond what Lutz describes as the "quantifiable link between the physical and sonic realms" (Lutz, 2005: 73). Indeed Lutz quotes Daniel Ott in describing the important role of the live musicians, saying that:

> "The idea was not to produce a bunch of random elements but to create a gesamtkunstwerk that benefits from the diversity of the participating musicians: integrating the performers as co-authors, as people and not just executing robots". (Lutz, 2005: 73)

2.4.3 Instruments and scores

Beyond pavilion collaborations, sound artists and architects have continued to build on this long association between the disciplines in developing a wide range of projects.

Possibly in response to the proliferation of alternative and graphical approaches to musical scoring during the 20th century, and the widespread emergence of acoustic interventions in architectural space through sound art practice, a number of new works appear to approach architectural contexts in one of two ways. The architecture is often either perceived as a sound object with unique acoustic properties to be activated and explored (an instrument), or as a set of abstract instructions to be interpreted and performed (a score). Whilst there are obviously exceptions to this (such as Achim Wollscheid's work focusing on architecture as an interface) (LaBelle, 2006: 251) this section will focus on examples of these two approaches.

2.4.3.1 Instruments

One example of dealing with architecture as an instrument is "Silophone" (2000) by architect / installation artist Thomas McIntosh and composer / sound artist Emmanuel Madan (working under the name

"[The User]"). The artists describe this project from the year 2000 as a "sonic occupation" of "an abandoned grain elevator in Montreal":

> "[The User] has transformed Silo #5 into a musical instrument by installing microphones and loudspeakers inside four of the elevator's empty grain storage chambers, making them accessible to the outside world via internet, telephone, and the "Sonic observatory." (*Silophone « Undefine, no date)*

An interesting aspect of this project is the fact it was made available for public performance through web and telephone access. Essentially acting as a large echo chamber, the architectural instrument requires human interaction to activate the acoustic, and to bring the empty structure to life. The piece brings to mind Jonathan Hill's description of architecture as being created by both the architect and the user:

> "The architect and the user both produce architecture, the former by design, the latter by use, as architecture is experienced, it is made by the user as much as the architect." (Hill, 1998: 6)

For their 2007 project at the Tate Modern Turbine Hall, Audialsense explored the architectural acoustic from a different perspective. Unlike "Silophone", "100Hz" was installed in a very public exhibition space, inviting people to explore the sound work in person.

The piece consisted of four main elements. First, a 100Hz tone, was produced to match an "omnipresent" sound created by transformers adjacent to the Turbine Hall, whose frequency fluctuates based on the actions (power consumption) of people living and working in the local area. The second element was a "site-specific chord" (Bavister, 2008: 103) of sound waves whose wavelengths were dictated by the measurements of the exhibition space. A third element incorporated sound waves based on the frequency range of male and female human

voices; and the fourth aspect was to incorporate sounds from within the architectural structure itself, using accelerometers to capture how the "building's infrastructure acts as a conduit/sounding board for all the bumps, squeaks and groans that general occupancy generates" (Bavister, 2008: 103). Paul Bavister of Audialsense describes the combined effect of this multi-faceted approach as "hearing the building as defined by both spatial and physical qualities" (Bavister, 2008: 103).

One of the results of the processes used for "100Hz" is the creation of standing waves – soundwaves whose amplitudinal peaks and troughs remain static in space. This creates an invisible, three-dimensional, acoustic topography throughout the space — a carefully tailored sound world that can be experienced physically as audience members move through the room.

Like La Monte Young and Marian Zazeela's "Dream House", "100Hz" highlights the subjectivity of architectural and acoustic experience. Their approach to site-specific sound means that two audience members can be stood in the same room, listening to the same generated sounds, but each may have a very different sensorial experience.

2.4.3.2 Scores

Equally, there are numerous examples of creative responses to architectural contexts employing aspects of the building as a non-traditional score to be performed in some way.

Where Audialsense represented room measurements as tone wavelengths, sound artist Christina Kubisch used the architectural proportions of the Ludwigskirche church in Old Saarbrücken (Germany) as the basis of the arrangement for her 1994 sound installation (and subsequent CD release) "Sechs Speigel", in which the building's

measurements "determine the rates of repetitions and pauses in vibrating drinking glasses" (All Music, no date).

In 2014, the digital sound artist Jon Bellona used the open source sequencer IanniX and sound design software Kyma to convert the proportions of the San Giovanni Elemosinario church (Venice, Italy) into a sound piece. His approach used virtual "playheads" moving around digitally rendered plans of the structure – thereby enabling spatial measurements to control temporal events. This approach is similar to the process used in my own project "Barographic" (2013), which also used IanniX to add virtual "playheads" to a 3D architectural model of the Sage Gateshead concert venue (*Barographic: Sage Gateshead | Ed Carter, 2013)*. However, "Barographic" also captured atmospheric pressure data from the venue as an additional context-specific device for composition (and scored for live musicians), providing an analogy for our phenomenological experience of architectural space. This project's approach is covered in more detail via its second iteration for The Lowry in Salford (2016), in section 4.2.

Composer and researcher Emma-Ruth Richards describes her own approach to interpreting architecture in great detail. What is striking from Richards' work is the multitude of different architectonic and perceptual elements she considers when developing her work. Richards describes her method of translating between spatial and temporal art forms in very subjective and personal terms as a form of "synaesthesia", but also sees architecture as a "score that has to be interpreted by a community". Whilst Richards' own focus is on the qualitative phenomenological experience architecture provides, many of her techniques for interpreting this take inspiration from quantifiable features within the space, such as "repetitive patterns, the placement of windows and arcs, particular moments of symmetry and balance, syncopation, interruption or cacophony and the phasing, pulsing, swelling nature of movement different sections of a structure" (Richards,

2014: 8). Therefore, whilst Richards distances her work from "Music of the Spheres and a symbolic relationship between the arts and proportions in nature" and the "golden section or ratio" (Richards, 2014: 8), it seems likely that her compositional response to architecture would indirectly be influenced by these concepts had the architect had employed them in the design process.

Another interesting example of interpreting architecture as a score is "Refurbishment" by Amenity Space from 2009, which I commissioned for an event titled "Arborescent" at Opera North (Leeds, UK). For this project, architects Tony Broomhead and Nicholas Kirk first took photographs of the performance space, and created a collage of the textures, fittings, fixtures and ornamentation that adorned the space (Carter, 2009). Due to the requirements of the event format, the resulting graphic score was then presented as a video projection in a linear format (read from left-to-right), for live performance by the music ensemble Psappha — who incidentally, are named after a Iannis Xenakis composition.
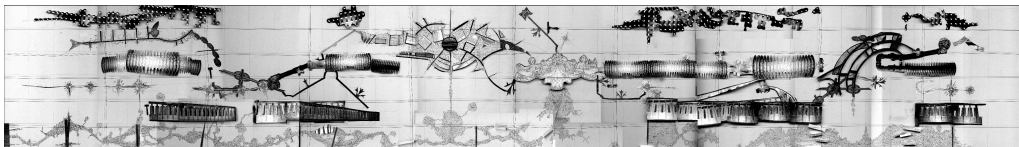
Figure 1: "Refurbishment" (2009) by Amenity Space

What is interesting about Amenity Space's deconstructivist approach is that despite their architectural roots, they don't use mathematical or proportional means to interrogate the space – the focus here is very much on texture and flow. This is in-keeping with a quote from Tony Broomhead when discussing the eponymous radio show the duo ran from 2007-2011 on Resonance FM. He describes the difficulty in communicating the experience of a place, and a building is more than the sum of its describable parts:

> "The emphasis is on conveying the atmosphere of a building or place: 'It's very difficult to talk about architectural space. If you're going to describe it, you can't do it justice — you need to experience the space.'" (Buxton, 2008)

2.4.4 Digital

A significant recent influence on approaches to qualitative and quantitative methods in connecting architecture and music has come from the emergence of digital technologies at the centre of this type of interdisciplinary creative practice.

Digital tools necessitate quantification at some point in the creative process. This may not be obvious to the person experiencing the finished work, and in some cases even the practitioner may be removed from any overtly numerical actions, but quantification is still present in the underlying method. Of course, this is not an unfamiliar position for architects or composers, as traditionally both roles have required a process of abstraction in order to realise their work. For example, a classical architect may have been thinking in terms of creating an experience through spatial and material craft, but communicating their concept required the medium of drawing and associated measurements of space. Equally, a classical composer might have been thinking in terms of creating an experience through temporal and sonic craft, but communicating their concept required the medium of written notation and associated measurements of time.

As a result, the evolution of the relationship between composer/architect and their technological tools is complex and somewhat symbiotic. It is not incompatible to accept that the "digital medium" of the computer has properties that "can have a dramatic effect on the musical potential of the objects that are made from the medium" (Brown, 2007: 8), whilst also acknowledging the argument that

"composition has not been led by technology, but has demanded it" (Grant, 2005: 233). Similar arguments can also be made concerning architects' use of Cartesian space long before the arrival of its modern incarnation as the virtual X, Y, and Z coordinates of 3D design software, whilst noting how the attributes of this virtual environment subsequently shape and inform contemporary architectural practice. Though it may be reasonable to assert that "Cyberspace alters the ways in which architecture is conceived and perceived" (Novak, 1994: 282), the creative tools to interact with that digital space are constantly adapting to the architect's needs.

As creative media, these tools can therefore be seen as examples of Marshall McLuhan's notion of how we have "extended our bodies" through new technologies, with the result of "abolishing both space and time" (McLuhan, 1994: 3) – thereby negating two fundamental elements when considering our personal experience of architectural and sonic interactions.

However, perhaps the most important effect of digital tools on the relationship between architecture and music is how the data is managed. There is a clear disconnect between the manner in which information is created or captured, how it is stored, and how it is interpreted and presented. At a basic level, a digital file is a series of numbers, and the format of its presentation is entirely dependent on the code that is chosen to read the file. This goes beyond Osborne's statement on the digital image that:

> "the creative potential of digitalized data to generate an in-principle-infinite *multiplicity of forms of visualizations*" (Osborne, 2010: 66)

The point being that the data needn't be realised in a visual format, it could be text, sound, or any other type of digital file. As Marcus Novak explains:

> "The raw materials of cyberspace are data, and processes that act on data. The fascination of this world comes from the interchangeability that the common underlying binary representation allows. Anything can be read, even if the format of its representation is unknown. Of course, everything can also be misread, but this is only a problem if one tries to read the information predisposed to find something conforming to a given format. If however, we scavenge this world for patterns to be used for the creation of further patterns, the problem disappears… (Novak, 2007: 7) A transformation may begin with a sound, fold the sound into a picture, the picture into a specification of a set of dance steps, the steps into a video, the video into another sound, and so on." (Novak, 2007: 10)

This idea of an implied interdisciplinarity in digital media, the concept that "any pattern can be made into a work of architecture, just as any pattern can be made into music" (Novak, 1994: 282), is reminiscent of Xenakis' concept of meta-art, which was similarly underpinned by the reappropriation, or re-mapping, of mathematical principles across media (Beilharz, 2004: 3).

Returning again to the words of Marcus Novak, it is evident the extent to which this quantitative approach to multiple interpretations of a single data source is influencing contemporary interdisciplinary practice:

> "As this brief exposition on the poetics of dataworlds shows, this is a place where buildings can flow and music can be inhabited. When this is understood, the distinction between architecture and music can be set aside." (Novak, 2007: 12)

This is also evident in contemporary practice. One recent example is Michael Fowler's work using Rhinoceros NURBS modelling software to design 3D architectural forms based on the aleatoric graphic score process for John Cage's "Variations III" composition (Fowler, 2012b: 39).

However, Fowler offers an important warning about this type of process, and how focusing on translating specific architectonic details may fail to capture the essence of the original concept:

> "When concepts such as architectural form becomes dramatized in music-space, we are often left only with the trans-media trace of proportional relationships and abstract dimensions as a representative of the multi-sensory, multi-dimensional experience of architecture" (Fowler, 2012b: 35).

Digital tools have also offered new methods through which artists can investigate the human body, and provided alternative means for representing how our physical form relates to, and interacts with, its immediate environment. For example, Memo Akten's collaboration with Quayola "Forms" won the 2013 Golden Nica (Prix Ars Electronica), by creating an animation that removed the human form itself, but retained its essence through a temporal study of bodily movement, and its interactions with the space it inhabits. Described on Akten's website:

> "Rather than focusing on observable trajectories, it explores techniques of extrapolation to sculpt abstract forms, visualizing unseen relationships – power, balance, grace and conflict – between the body and its surroundings." (*Forms - Memo Akten*, no date)

Another interesting application of the human body and architecture in digital practice is Lozano-Hemmer's 2001 project "Body Movies", in

which audience members can cast shadows of their own body onto the surrounding architecture, creating human forms of between two and twenty-five metres (*Rafael Lozano-Hemmer - Project 'Body Movies'*, no date). These shadows are then filled with projected portraits of other members of the local community. The scale of these interactive, collaborative human projections onto nearby buildings forces the audience to reconsider the relationship between the human body and the built environment. The piece is part of Lozano-Hemmer's series he has called "relational architecture", described as "large-scale interactive events that transform emblematic buildings through new technological interfaces" (*Rafael Lozano-Hemmer | Liverpool Biennial of Contemporary Art*, 2002)

However, within the context of this research, it is appropriate to retain a focus on the quantifiable approach necessitated by any digital process. For example, whilst artists, composers, and architects have all taken inspiration from nature throughout history, digital tools place a numerical filter on how that influence is interpreted and applied. An interesting example from the world of digital composition is Tim Blackwell's "Swarm Music", which takes inspiration from natural examples of self-organisation such as the behaviour of termites, fish shoals, and starling flocks (murmurations) (Blackwell et al., 2014), and how these actions relate to the process of live improvised music performance. Using a similar process to Craig Reynolds' 1986 algorithm "Boids" (Reynolds, 2001), "Swarm Music" employs a mathematical model to simulate flocking behaviour in order to create new "improvised" music, providing the experience of a seemingly "organic" performance based on a decentralised system of organisation, but achieved through purely numerical generative and geometric programming (Blackwell and Young, 2004).

2.5 Summary

The aim of this contextual review is to evidence the long history of perceived connections between architecture and music, and to demonstrate some of the different means by which practitioners and theorists have sought to observe and explore similarities between the disciplines.

Returning to the notion that this type of work has taken either a numerical or experiential approach, it becomes apparent that the relationship between the two methods is far more complex and inter-related, and the two are certainly not mutually exclusive. For example, one practitioner may choose a certain set of frequencies to represent an architectural context based purely on their perception of the emotive, aesthetic properties that they exhibit within the space. Another practitioner may analyse the mathematical proportions of the same space to anticipate resonate frequencies, and thereby select the same set of tones. Each of these represents the artist's subjective attempt to capture an essence of the architectural context through a process of abstraction, and this research aims to draw on aspects of both approaches without hierarchy.

Through an iterative process of praxis alongside literary and contextual review, this research aims to build on this extensive body of on-going interdisciplinary work, exploring methods which can be seen to bridge the perceived qualitative/quantitative (or aesthetic/numerical) divide in some respect.

As a seminal work in this field, Alvin Lucier's "I Am Sitting in A Room" provides an interesting reference point for the following practical research projects. As previously mentioned, whilst Lucier's approach to sound and architecture was influenced by the "measurable" attributes of sonic events (Reynolds, 2001), in practice, the piece itself naturally

adapts and responds to the sonic interactions between the subject and their surroundings, without any means of explicit measurement.

It is interesting to note that Lucier described his process as destroying every recognisable feature of his recorded voice with one possible exception – rhythm (Kahn, 2009: 28). Much as the work "I Am Sitting in a Room" can be seen as an enlightening combination of aesthetic and numerical approaches to connecting sound and architecture, the philosopher Henri Lefebvre considers rhythm itself to be a tool for interrogating our surroundings that bridges qualitative and quantitative approaches, and this concept forms the basis of the first phase of practical research.

3 Practical and Further Contextual Research

3.1 Overview

As a programme of practice-based research, the following three chapters build on the contextual material covered in the general contextual review, in order to develop a series of new creative works as a process of "thinking through making" and "making through thinking" (Ingold, 2013: 6; Shaw, 2018: 11).

The projects depict an evolving, iterative process, documenting practitioner experience by way of reflections and observations made in response to the development and presentation of the works. Three main research themes emerged from this process: rhythm, scale and liminality, each of which is explored through associated practical projects, and prefaced by additional tailored contextual review.

The main practical projects produced in exploring these themes were:

Practice A — " Barographic: The Lowry"
Practice B — "Journey"
Practice C — "SCALE"
Practice D — "My Modulor"
Practice E — "Dunelm House project"

These projects are documented in detail below. Information about two additional projects created during the research period ("195 Piccadilly" and "Bridges") is also included in the appendices.

As previously established, this research considers how connections have previously been made between architecture and music, working from the perspective that each of the disciplines creates an experience that is both spatial *and* temporal. Therefore, the issue is not translating *between* the spatial and temporal, but how to reconcile and incorporate *both* of these elements in the creation of a new piece of creative work.

Thinking back to Sven Sterken's observations about methods typically used to relate architecture and music, the terms he uses are equally applicable to either discipline, as both the spatial and temporal aspects of either architecture or music can be interpreted through "intellectual" or "phenomenological" methods — either analysing them in quantitative terms through "numerical principles", or in respect of their qualitative "aesthetic effects" (Sterken, 2007: 31).

In response to this, the direction of this research moves away from bridging the spatial aspects of architecture and the temporal aspects of sound, shifting the focus towards creating new interdisciplinary work using methods that in some way aim to incorporate both quantitative *and* qualitative interpretations of their architectural contexts.

4 Rhythm

4.1 Contextual review

As a practitioner, part of the inspiration for this research came from a personal interest in the manner in which architects can invoke a sense of rhythm and dynamics through the built environment.

Much like our experience of music and architecture, by definition, rhythm is both spatial and temporal:

> "A strong, regular repeated pattern of movement or sound." (Definition of 'Rhythm', 2019)

Movement and sound both depend on their spatial and temporal qualities in order to exist. Also, both are experienced as a qualitative, aesthetic experience, but can be interpreted or described through quantitative, numerical means.

For these reasons, "rhythm" was chosen as the first research theme for this programme of practice-based research, which finds parallels with the writings of the influential French philosopher and sociologist Henri Lefebvre.

4.1.1 Lefebvre: Rhythmanalysis

In his book Rhythmanalysis, Lefebvre proposed "rhythm" as a transferable methodology for analysing our surroundings, and one that he claims unifies our perception of the qualitative and the quantitative in a single toolset.

> **"Rhythm** reunites **quantitative** aspects and elements, which mark time and distinguish moments in it – and **qualitative**

aspects and elements, which link them together, found the
unities and result from them." (Lefebvre, 2013: 18)

Fundamental to Lefebvre's approach is the manner in which he links
our perception of spatial and temporal events, which he does through
the inclusion of an "expenditure of energy" in his process:

"Everywhere where there is interaction between a place, a time
and an expenditure of energy, there is **rhythm**." (Lefebvre,
2013: 25)

This statement acknowledges perception of the subject matter
(whatever form it may take) as an active process that must be "lived",
with both a spatial and temporal dimension. Using this definition, it is
possible to apply Lefebvre's concept of rhythm to virtually any context.

As a simple example, the "place" could be a street, the "expenditure of
energy" could be walking along the street, and the "time" would be the
duration of the journey. Alternatively, the "expenditure of energy" could
be a person clapping their hands (and the resulting sound wave it
produces), the "place" could be the space through which the sound
travels, and the "time" element could be the rhythm of the clapping, or
the time it takes the sound to travel between certain points (e.g. the
source and the listener), or the difference between the audible delays
created by reflections off different surfaces in the surrounding area.

Importantly, the open and transferable nature of Lefebvre's method is
equally applicable to a static architectural form, a piece of music,
natural or mechanical processes, or complex social and political
interactions. The "energy expended" could be merely the movement of
an eye across a page of a book, the wind blowing through a tree, the
expansion of the Universe, or all these things together – Lefebvre's

approach certainly cannot be faulted for its level of flexibility. In Lefebvre's own words:

> "[The rhythmanalyst] is always 'listening out', but he does not only hear words, discourses, noises and sounds; he is capable of listening to a house, a street, a town as one listens to a symphony, an opera. Of course, he seeks to know how this music is composed, who plays it and for whom… Attentive to time (to tempo) and consequently to the repetitions and likewise to differences in time, he separates out through a mental act that which gives itself as linked to a whole: namely rhythms and their associations. He does not only observe human activities, he also hears [*entend*] (in the double sense of the word: noticing and understanding) the temporalities in which these activities unfold." (Lefebvre, 2013: 95)

Whilst beyond the scope of this study, Lefebvre's reference to "repetitions" and "differences" should be considered in the context of philosopher Gilles Deleuze's 1968 book "Difference and Repetition", in which Deleuze aligned the qualitative with pure difference and the quantitative with repetition (Wells, 2013: 8). For a comprehensive analysis of Deleuze's writing on this topic (and others), see Will Schrimshaw's informative paper "A Sound Takes Place" (Schrimshaw, 2011) in which he describes his own research on "sonorous-individuation" as being "spatio-temporally contingent" (Schrimshaw, 2011: 265), placed within the context of Gilles Deleuze's theory of individuation (Schrimshaw, 2011: ii).

Lefebvre's overarching method therefore provides a framework for observing not just a single "rhythm", but offers a toolset for interpreting layer upon layer of spatial and temporal interactions, the combination of which theoretically capture the complexity of their surrounding context.

In "Seen from the Window", Lefebvre provides arguably his most vivid depiction of applied "Rhythmanalysis", describing the "multiplicity of noises" (Lefebvre, 2013: 38) heard from his balcony above a bustling Rue Rambuteau in Paris in the mid 1980s (Schrimshaw, 2011: 101). He suggests that "Noise, chaotic, has no rhythm" (Lefebvre, 2013: 37), but how "the attentive ear begins to separate out, to distinguish sources" (Lefebvre, 2013: 37), and how it becomes evident that the "rhythms respond to one another" (Lefebvre, 2013: 38) as an audible manifestation of "social organisation" and the "daily grind" (Lefebvre, 2013: 40).

Some of the more involved events described in "Seen from the Window" offer a sense of the level of complexity involved in these interactions, and on more than one occasion Lefebvre likens the multi-layered, evolving, responsive sonic tapestry to the behaviour of water:

> "Sometimes, the old cars stall in the middle of the road and the pedestrians move around them like waves around a rock" (Lefebvre, 2013: 39).

> "Currents traverse the masses. Streams break off, which bring or take away new participants… The tide invades the immense square, then withdraws: flux and reflux." (Lefebvre, 2013: 45).

Lefebvre's analogy is reminiscent of architect and composer Iannis Xenakis' description of a political crowd as an example of stochastic principles in his book "Formalized Music". Xenakis describes the group as a "human river" (Xenakis and Kanach, 1992: 9), and how the sounds move around the crowd as a "wave of transition" (Xenakis and Kanach, 1992: 9), as one rhythm descends into chaos before being gradually replaced by the next.

Much like Lefebvre, Xenakis begins with a description of experiencing the totality of a chaotic noise event ("such as the collision of hail or rain with hard surfaces") as "thousands of isolated sound…[a] multitude of sounds" (Xenakis and Kanach, 1992: 9). He then goes on:

> "Everyone has observed the sonic phenomena of a political crowd of dozens or hundreds of thousands of people. The human river shouts a slogan in a uniform rhythm. Then another slogan springs from the head of the demonstration; it spreads towards the tail, replacing the first. A wave of transition thus passes from the head to the tail. The clamor fills the city, and the inhibiting force of voice and rhythm reaches a climax. It is an event of great power and beauty in its ferocity. Then the impact between the demonstrators and the enemy occurs. The perfect rhythm of the last slogan breaks up in a huge cluster of chaotic shouts, which also spreads to the tail… Imagine, in addition, the reports of dozens of machine guns and the whistle of bullets adding their punctuations to this total disorder. The crowd is then rapidly dispersed, and after sonic and visual hell follows a detonating calm, full of despair, dust, and death... The statistical laws of these events… are stochastic laws." (Xenakis and Kanach, 1992: 9).

Despite their differing approaches, both Lefebvre and Xenakis accept that, regardless of the complexity of the subject matter, their methods of observing and interpreting seemingly chaotic "natural events" (Xenakis and Kanach, 1992: 9) are quantifiable in some way.

This is perhaps unsurprising for Xenakis, whose work has been described as "inherently mathematical" (LaBelle, 2006: 185), but Lefebvre is also very clear about his acceptance of the quantifiable nature of temporal events, and that the principle applies to multiple art forms – including architecture:

"Far from resisting quantity, time (duration) is quantified by *measure*, by melody in music, but also in deed and language. Harmony, which results from a spontaneous ensemble, or from a *work of art*, is simultaneously quantitative and qualitative (in music and elsewhere: language, movements, architecture, works of art and diverse arts, etc.)." (Lefebvre, 2013: 18)

It is these quantifiable attributes that make "rhythm" a method particularly suited to digital practice. A computer may be programmed to capture and interpret qualitative information, but at some point in the process, quantification is inevitable due to the nature of digital information. With this in mind, the approach undertaken in the first practical research projects (documented below) employs digital techniques to explore architectural context, exploring rhythm as a context-specific creative tool.

4.1.2 Rhythm in practice

Aspects of Lefebvre's approach to Rhythmanalysis can be observed in the work of numerous creative practitioners, one recent example being composer Emma-Ruth Richards. Her description of her own working process when responding to architectural contexts describes a temporal journey through her spatial surroundings. Richards describes her process as: "musically translating my sensory engagement with the rhythm of repetitive patterns… and the phasing, pulsing, swelling nature of movement different sections of a structure" (Richards, 2014: 7-8).

However, elements of Richards' approach arguably align more closely with Steen Eiler Rasmussen's discussion of rhythm in "Experiencing Architecture", which focuses on rhythms inferred from ocular and geometric analyses of various architectural façades (Rasmussen, 1964: 127-158). Looking beyond architectural contexts, there are also clear parallels between this interdisciplinary perspective and the "visual

rhythm" explored by (among others) Paul Klee in his graphical interpretation of "Bach's Sonata no. 6" (Vergo, 2011: 15-16), and numerous graphic scores created throughout the second half of the twentieth century and beyond[1].

One of the key points regarding Rasmussen's approach to rhythm concerns the connection that rhythm can create between the viewer and the architect:

> "If you feel that a line is rhythmic it means that by following it with your eyes you have an experience that can be compared with the experience of rhythmic ice-skating, for instance. Often the man who forms architecture also works rhythmically in the creative process itself. This results in a regularity which may be very difficult to express in words but which is spontaneously felt by those who have the same sense of rhythm." (Rasmussen, 1964: 135)

Whilst Rasmussen's perspective may offer a simplified interpretation of rhythm in architecture when compared with Lefebvre's, it also suggests that analysing rhythm in architectural form may provide a window into the creative intent of the architect, by experiencing the same "sense of rhythm" they were expressing through their design (Rasmussen, 1964: 135). Returning to the overarching research aim of responding to architectural contexts, Rasmussen's approach to rhythm therefore offers the potential of creating new work that reflects the creative process the architect was undertaking in developing the site.

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[1] Interestingly, in one early graphic score, Studie II (1954) by Karlheinz Stockhausen, the pitch and dynamics elements could be easily realised as an architectural form, by interpreting them as the plan and elevation aspects of an architectural drawing. It has also been noted that aspects of Treatise (1963-67) by Cornelius Cardew bears a striking resemblance to Constructivist architecture (*Vocal Constructivists | Sounding Graphics*, no date).

Rasmussen appears to suggest that this approach to rhythm creates a methodology for using the "measurable" (in this example, the built environment) to explore the "unmeasurable" (the architect's creative intent) – to use Louise Kahn's terminology. This concept informs the approach taken in the two practical projects developed within the "rhythm" section of this piece of research.

4.2 Rhythm: Practical research projects

The following section documents two practical research projects, each developed in response to a specific architectural context (The Lowry in Salford, UK, and Singapore Art Museum [SAM] in Singapore respectively).

For each project, a brief overview of the architectural context is provided (and the commissioning context where relevant), followed by a description of the creative process, the nature of the presentation, and any associated observations.

The approach for both projects stems from Lefebvre's notion that analysis of "rhythm" can encompass both the quantitative and the qualitative when interpreting a spatial and temporal context or event.

The methods for applying this to each context varies, but a central process simply treats the building envelope as a graphic score, using sound to highlight "rhythms" within the architectural form, which relates to Rasmussen's suggestion that rhythms within the façade of a building can potentially provide insight into the architect's creative process.

4.2.1 Practice A: "Barographic: The Lowry"

4.2.1.1 Context

"Barographic: The Lowry" was commissioned and presented by The
Lowry (Salford, UK) for the exhibition "Right Here, Right Now",
November 2015 – February 2016. The project reprised a concept
originally developed for a composition, performance, projection, and
installation at Sage Gateshead, commissioned as part of Festival of the
North East in 2013 (and performed again at the venue's 10th birthday
celebrations in 2014).

The "Barographic" process was originally developed to explore the way
architects invoke a sense of rhythm and dynamics in the built
environment, and to represent our perception of 'atmosphere' –
something less tangible (and therefore less measurable), but a term
often used to express our phenomenological experience of buildings
and public spaces.

Many parallels can be drawn between Sage Gateshead and The Lowry,
both being publicly-funded, high-profile, cultural venues, designed by
leading contemporary British architects (Norman Foster and James
Stirling / Michael Wilford respectively). Both buildings are located in the
North of England (Gateshead and Salford), each within waterside urban
regeneration developments.

Both are clad in stainless steel, but one notable difference in visual
terms relates to the flowing curves of the roof at Sage Gateshead, in
contrast to the strict geometric volumes that lock together to form The
Lowry.

4.2.1.2 Process and presentation

There are two distinct elements to this piece of work, which come together at the end of the process to form the final piece as a live performance.

One aspect of the work uses the architectural proportions of the venue as an animated, 3D sound sequencer. The second aspect of the work involves capturing atmospheric pressure data (during a public installation period at the host venue) in the form of barograms, which are then used as graphic scores for additional layers of musical composition. The final presentation combines the sounds and rhythms produced by both processes in a live music performance, alongside synchronised video of the animated graphic score processes that produced the composition.

The installation version is available to view online (https://vimeo.com/339952876), as is the performance version, with audio recorded during rehearsals (https://vimeo.com/340200593).

4.2.1.3 3D architectural sound sequencer

In reference to the manner in which architects can invoke a sense of rhythm and dynamics in the built environment, an animated 3D sound sequencer was created based on the proportions of the venue.

Using architectural plans and elevations (provided by The Lowry), images and aerial photography, a 3D model of the venue's external form was created using the free 3D modelling software Sketchup. The 3D model was exported as an X,Y,Z point cloud which in turn was reformatted through a Processing patch (with assistance from Dr Tom Schofield, Newcastle University), to import the point cloud into the graphical open source sequencing software IanniX

(https://www.iannix.org). It is worth noting that the design of the IanniX software itself is (perhaps unsurprisingly) directly influenced by the creative practice of Iannis Xenakis (*What is IanniX? | IanniX*, no date), and as a result it provides a useful framework for linking spatial and temporal events (using Cartesian coordinates and a timeline).

After importing the 3D model of The Lowry in IanniX, a number of additional paths were created, each following major structural details, and virtual "playheads" (orange rectangles on Fig. 1) were added to these paths – with the result that the animated "playheads" could move around different sections of the architectural form. Trigger points were then added to the model at key features (e.g. corners), which when triggered by the moving "playheads" would send messages over midi to Ableton Live, which acted as the sound synthesiser.

As a result of this process, the relative spatial proportions of the building are furnished with temporal attributes, which are realised as synchronised video and sound.
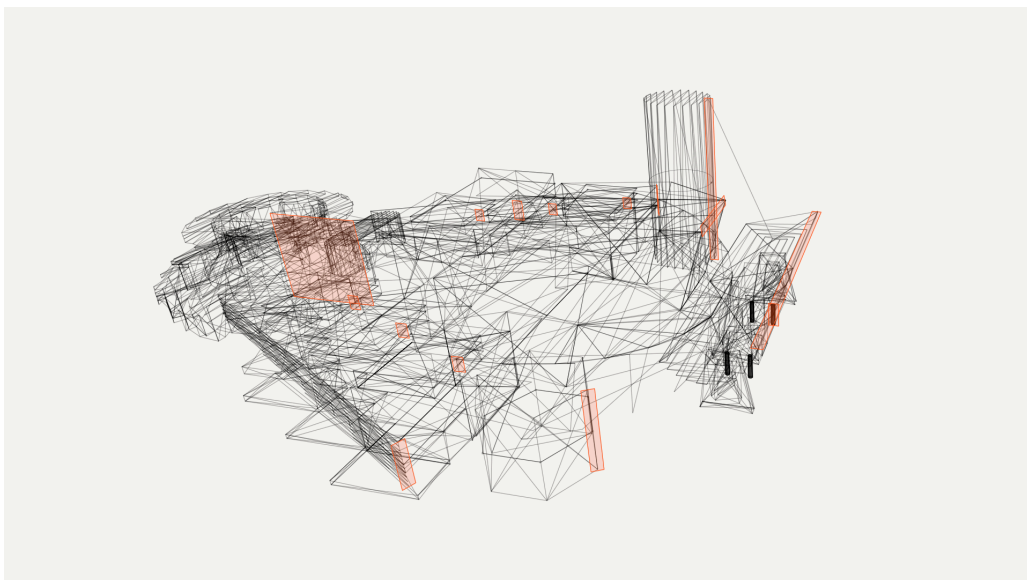
Figure 2: "Barographic: The Lowry" (2015) by Ed Carter
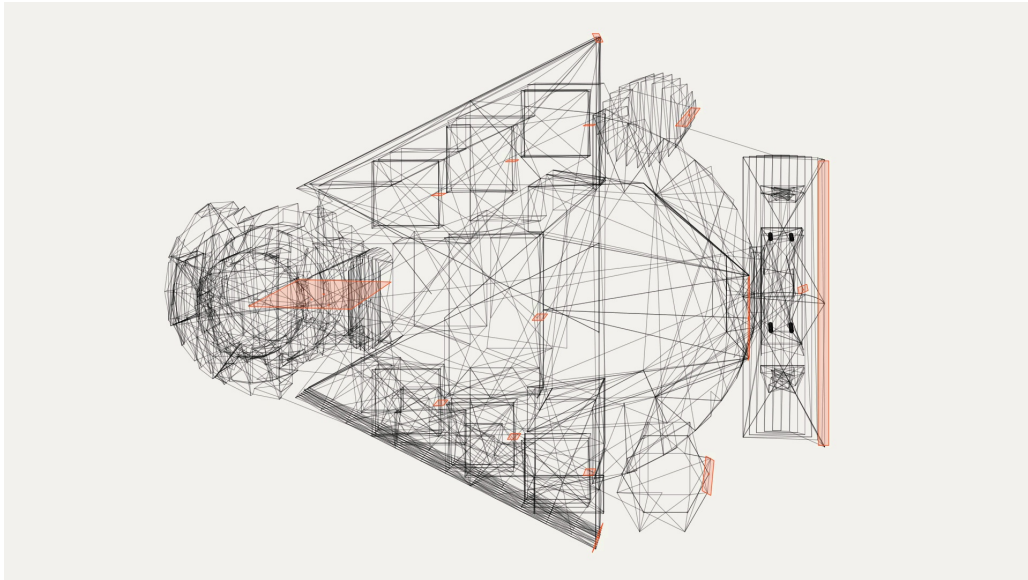
Figure 3: "Barographic: The Lowry" (2015) by Ed Carter
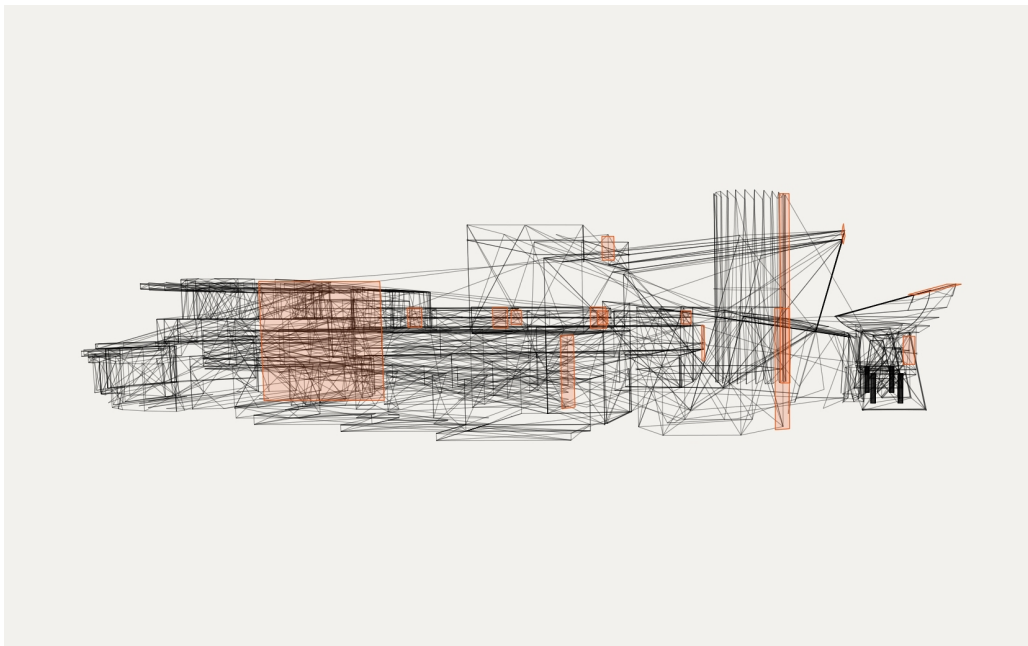
Figure 4: "Barographic: The Lowry" (2015) by Ed Carter

With the exception of a stepped section around the largest circle, the pitches associated with each part of the structure do not represent any architectural details, and are purely aesthetic choices (and randomised in one instance). The musical scale used is a Bb minor pentatonic scale, selected to reduce sonic dissonance in the results, and for ease

of performance (due to the limited rehearsal time available for the live performance).

The architectural form is therefore used purely as a rhythmic sequencer, creating multiple overlaid rhythms based on the relative proportions of different sections of the structure, but with the architecture having no bearing on the pitches used in the piece. Using Henri Lefebvre's terminology from "Rhythmanalysis" (Lefebvre, 2013: 25), the "place" is The Lowry (or more accurately, its component parts), the "time" is the duration for the animated "playheads" to travel along their associated paths, and the "expenditure of energy" is the notion of movement as depicted by the "playheads" around the structure. This raises the question about whether or not the virtual representation of movement around a digital 3D model constitutes an "expenditure of energy". For the purposes of this study, perhaps it is simpler to consider the expenditure of energy to be the movement of the viewer's eyes as they follow the "playhead" along its path.

For the installation period, the 3D architectural sequencer was captured as a video file, and presented as a looped, single-screen video (with stereo sound) in the gallery space.

4.2.1.4 Barometric pressure data

The animated 3D sequencer was inspired by the idea of architects creating a sense of rhythm and dynamics in the built environment, but the project also explores the less tangible phenomenological experience of visiting the venue by way of an analogy, monitoring and repurposing changes in atmospheric pressure.

In order to capture this information (and make it accessible to audiences), a clockwork barograph was installed in the gallery space at The Lowry for the duration of the installation period. Over the course of

a week, the barograph responded to atmospheric pressure, drawing a line on a paper chart to record the changes. Each week, invigilation staff wound the barograph's clockwork mechanism, replaced the completed chart (barogram) with a blank one, and added the completed barogram to a display case in the gallery, alongside the barograph, and the looped video/audio presentation of the 3D architectural sequencer.
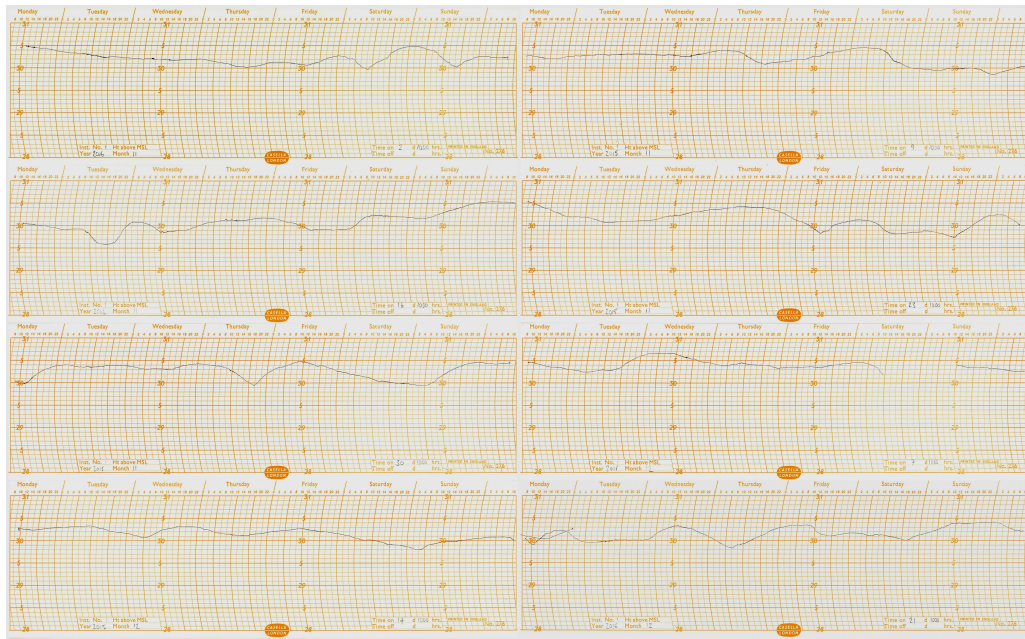
Figure 5: Atmospheric pressure data (barograms) from "Barographic: The Lowry" (2015) by Ed Carter

The charts were also digitally scanned, for use as graphic scores in the final sonic composition, which combined the outputs from the architectural sequencer and the barometric pressure data.

In interpreting the barograms as graphic scores, they were read chronologically - left to right as they were drawn over the installation period. Using IanniX software again, an animated "playhead" was overlaid onto the image, dictating the speed at which the score was to be read, and to create a video that articulated the composition process.

The approach taken for translating the score into the Western musical scale was simplistic and literal. Similar to traditional sheet music, the score was read from left to right. The Y-axis was used to determine pitch (low notes at the bottom of the sheet, high notes at the top), and the X-axis was used to represent time. This approach also reflects the manner in which Iannis Xenakis designed the early UPIC computer system, which creates graphic scores by drawing "arcs" to dictate changes in frequency over time (Xenakis and Kanach, 1992: 329). This can be seen in action in a video of his composition Mycenae Alpha (Craig, 2007).

Relating this aspect of the process back to Lefebvre's "Rhythmanalysis" (Lefebvre, 2013: 25), the "place" again is The Lowry, the "time" is the installation period (broken down into the weekly barogram charts), and the "expenditure of energy" is the rise and fall of barometric pressure.

4.2.1.5 Presentation

During the installation period at The Lowry the working process was on display, in the form of:

- A mechanical barograph, capturing changes in atmospheric pressure
- A display case, containing the completed weekly barograms (pressure charts)
- A single channel video with stereo sound, presenting a looped video of the 3D architectural sequencer

After the eighth week of the exhibition period, the results of the two composition techniques were combined to create a final composition, which was then traditionally scored for performance in the gallery by a live ensemble (vibraphone, violin I, violin II, viola, cello, piano, electronics).

For the performance, each player performed with an in-ear click track, to maintain synchronicity between the live instrumentation and the video playback. Two screens displayed video of the two animated scores (the 3D architectural sequencer, and the barograms with animated playheads), allowing audiences to make a visual connection between the music and the underlying composition processes. No audio was included with the video playback, as these elements were transcribed for performance by the live ensemble.

The arrangement of the final piece was primarily chronological, with the string instruments each playing the same melody (derived from the barometric pressure charts). The melody is started by the cello and viola, then followed one "week" (or 21 bars) later, by violin II, and again another "week" later by violin I. The vibraphone was given the part created from the 3D architectural sequencer as a one-minute loop (matching the installation version), and the piano played a loop of the combined melodies from all eight weekly barograms overlaid in two looped sections (representing the two months of the installation period).

Figure 6: Live performance of "Barographic: The Lowry" (2016) by Ed Carter, photo Beryl Graham

4.2.2 Observations from Practice A: "Barographic: The Lowry"

The observations from this first practical research project fall into three main areas, covering issues of scale and scalability, the implications of discrepancies between the approaches to interior and exterior perception of the building, and unexpected outcomes attributed to the use of Lefebvre's "Rhythmanalysis" as a tool for exploring architectural contexts.

4.2.2.1 Scale and Scalability

A recurring issue during the development of this piece concerned approaches to scale and scaling, and their impact on observations of rhythm. The process behind the work relies on multiple translations of data, and in each instance, subjective and aesthetic decisions fundamentally affect the nature of the results.

One obvious example is the speed at which the "playheads" move around the 3D architectural sequencer. This dictates the underlying tempo of the resulting sonic composition, but also impacts the audience's visual interpretation of the architectural subject. The final visual presentation of this visual scaling was dictated by a pragmatic decision, i.e. the size of the screens available at the gallery. As a practitioner, this process of scaling is highly evident when using digital production techniques (where a process of scaling is often overtly quantifiable), and reinforces John Maeda's assertion about "the absence of a single default scale on the computer." (Maeda, 2000: 142)

As a result, much of the scale and scaling of the piece can be seen as somewhat arbitrary. Each aspect of the architectural form (and its associated visual and sonic representation) only relates proportionally to other parts of the structure as depicted within the piece, removed from the wider environmental and social context, and (perhaps most importantly) from the people who inhabit and animate the space. Gerald Adler describes Le Corbusier as being "spellbound by the image of (scaleless) architecture devoid of people" (Adler et al., 2011: 2) despite his attempts to place the human form at the heart of his architectural practice, and arguably this creative process has the potential to create work that falls into a similar trap.

This observation is the reasoning behind the focus of the second area of research in this study, looking at issues relating to "Scale", and paying particular attention to anthropometric approaches to scale (see Practice C: "SCALE", in section 5.2.1).

4.2.2.2 Interior vs Exterior

Whilst "Barographic: The Lowry" conceptually references its architectural context from both an external and internal perspective, the approach to interior space employs a generalised analogy aimed at

highlighting the intangible aspects of phenomenological experience, as opposed to using rhythm as a method for engaging with any quantifiable relationship between humans and their architectural surroundings.

This approach can be seen as an attempt to articulate Louis Kahn's desire to retain the "unmeasurable", in spite of an inevitable process of quantification at some point in the creative process (Lobell and Kahn, 2008: 48). However, given that phenomenological experience is so subjective, for future work it seemed logical to look towards a creative approach that is less generalised, and methods that conceptually reflect a personalised experience of architectural context.

Reflecting again on Kahn's associated comments about the creative process moving between the "unmeasurable" and the "measurable" (Lobell and Kahn, 2008: 14), it becomes clear that this is not a journey that users/visitors/inhabitants have to make along with the architect. The architect needs to consider the "measurable" for pragmatic reasons (Lobell and Kahn, 2008: 48), but someone experiencing a building needn't consider their surroundings in quantifiable terms unless they need to communicate their experience in some way (as the poet must do through written or spoken word, and an architect must do through plan and elevation drawings). This also relates to Lefebvre's interpretation of the pragmatic quantification of creative practice:

> "Measure and writing correspond to the *practical* needs of music" (Lefebvre, 2013: 73).

With this in mind, when creating new work in response to architectural contexts it seems that overtly numerical (measurable) methods are perhaps more conceptually suited to an exploration of the architect's creative process, reflecting this critical step in the realisation of their initial concept. Conversely, as quantification is not an essential step for

someone experiencing an architectural context, it may seem more appropriate to reflect their subjective phenomenological experience through more direct (and less measurable) personal interactions with their environmental surroundings.

As a result of this observation, the focus of the second practical phase of this research concerns subjective experience of interior space (see Practice C: "SCALE", in section 5.2.1), and personalisation of creative responses to architectural context (see Practice D: "My Modulor", in section 5.2.3).

4.2.2.3 *"Rhythmanalysis" as a tool for investigating architectural context*

The Lowry provides a fascinating subject for a study on architectural rhythm, due to the strict geometric volumes employed within its structure. Starting from a broadly triangular plan, different sized squares, rectangles, cylinders, trapezoids, and a hexagonal tower, all lock together to form the venue.

These shapes are readily understood in numerical terms, and therefore lend themselves to simple translation into accepted musical concepts. Applying rhythm through movement around these structures immediately presents overlaid, syncopated rhythms, as the different "playheads" respond to the one, two, three, four, or six-sided shapes.

Whether observing these rhythms opens a window to the working process of the architect is a matter of debate, but it is difficult to dispute that the architectural and the musical outputs are both built from the same geometric forms through which the architects chose to realise their creative vision. A change to any one of these geometric forms would directly affect both the structural and sonic results.

As Lefebvre said, the Rhythmanalyst "seeks to know how this music is composed, who plays it and for whom" (Lefebvre, 2013: 95), and as such, the project included a period of wider research into the architectural context. It transpires that early iterations of the design included a tower that was octagonal or square in plan with a cylindrical top section (Wilford and Royal Institute of British Architects, 1996: 152-3), but that a full cylindrical tower was chosen for the final design. Clearly an octagonal element to the animated graphic score process would have created very different sonic results, as it would for the architectural form.

Further reading revealed that architect Sir James Stirling, the "founder and most ebullient partner" at James Stirling Michael Wilford and Associates (Wilford and Royal Institute of British Architects, 1996: 17), died unexpectedly, shortly after the practice was selected to build The Lowry. The design alteration could have been for any one of a number of practical reasons, such as cost or change of purpose, but it raises the interesting question as to whether the geometric "rhythm" associated with the cylinder was in-keeping with the initial concept (in which it was an octagonal tower), and whether it could be indicative of a shift in creative control mid-programme.

The underlying point, however, is not whether or not Sir James Stirling and Michael Wilford held different opinions about the relative merits of cylindrical or octagonal towers. The important observation here is that, through a practical interpretation of Lefebvre's "Rhythmanalysis" process, additional historical contextual information has been uncovered, which can feed into the creative process. Had the compositional process simply relied on my subjective aesthetic experience of visiting The Lowry, then the death of the lead architect, and the changing creative dynamic may not have become apparent. This information came to light too late to incorporate into the composition for Practice A: "Barographic: The Lowry", but could easily

have provided another layer of rhythmic activity which reflected the architectural context as it developed during the creative process.

This observation lends some support to Lefebvre's approach to rhythm as "a *tool* of analysis rather than just an *object* of it" (Elden, 2013: 5), and a technique which has the indirect ability to inform our understanding of an architectural context through the process itself, rather than through any sonic interpretation of perceived rhythms in the fabric of the building.

An equivalent observation is made in response to Practice B: "Journey", in which a similar compositional approach is applied to the façade of Singapore Art Museum.

4.2.3 Practice B: "Journey"

4.2.3.1 Context

Commissioned for Singapore Night Festival 2016, "Journey" was a collaborative project with NOVAK, who specialise in large-format projection works. The visual component of the commission (developed by NOVAK) was designed to be in-keeping with the wider themes of the festival, whereas the sonic component that I developed (which is the focus of this research) responded primarily to the architecture of the host venue (Singapore Art Museum), with additional sound effects tying the sound piece to the projected material.

The project was developed remotely (from Newcastle-Upon-Tyne, UK) with the creative team only arriving on location for installation and testing in the days leading up to the festival. Keith Daniels of NOVAK undertook one site visit in advance of this, to collect measurements and photographs of the building façade.

In contrast to The Lowry in Salford, Singapore Art Museum does not represent contemporary architecture, but a former school building dating back to the mid 19th century, which received "national monument" status in 1992. (Tan, no date).

4.2.3.2 Process and presentation

As well as referencing photographs of the building, NOVAK provided 2D and 3D models (Figure 7 and Figure 8) of the façade that they created in order to develop the visual content, and to plot projector positions. I used these as the starting point for developing a "graphic score" responding to the building façade.

On first viewing the photographs and models, the building proportions appeared to demonstrate extensive use of "golden ratio" rectangles in the design, and as such, this became a focus of the compositional approach. The golden rectangle is defined as "a rectangle whose width is to its length as the length is to the sum of the width and length" (Definition of 'Golden Rectangle', 2018). The golden ratio is represented by the Greek letter Phi (Φ), and is often applied using the rounded decimal ratio of 1:0.618.

Conceptually, the approach was comparable to the technique used for Practice A: "Barographic: The Lowry", using the idea of virtual "playheads" moving around the architectural form, triggering sounds as they encounter key architectural features. In this instance, these features were the golden rectangles observed on the front elevation of the building, with the notional "playheads" taking both horizontal and vertical routes across the symmetrical façade.

Video of the presentation (with NOVAK's projected work) is available online (https://vimeo.com/81089715).
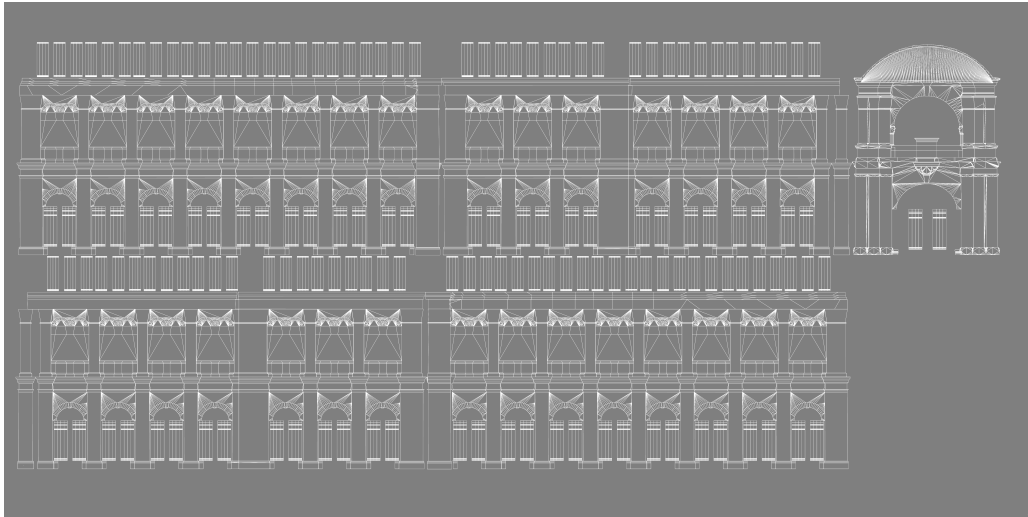
Figure 7: Singapore Art Museum UV map by NOVAK
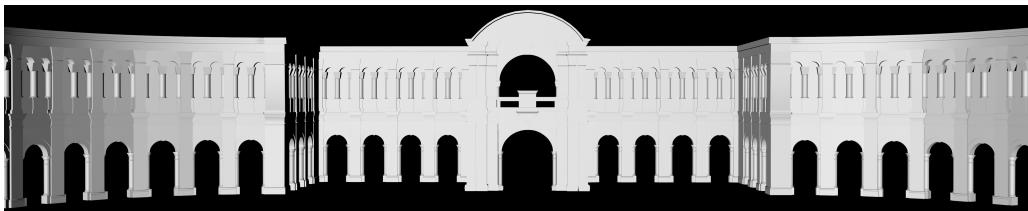
Figure 8: Singapore Art Museum 3D model by NOVAK

4.2.3.3 Composition

The two-storey Singapore Art Museum building frontage consists of a central entrance area, with symmetrical repeated bays to either side, curving around an outdoor courtyard. For the purposes of the graphic score, only a single pair of repeated bays is included, with the understanding that each section could be looped in the composition by altering the path of the "playheads", in order to replicate the repetition displayed in the architecture.

As seen in Figure 9 (below) both the proportions of the central entrance area and each two-storey bay can be divided by multiple portrait and landscape golden ratio rectangles (ratio 1:0.618).
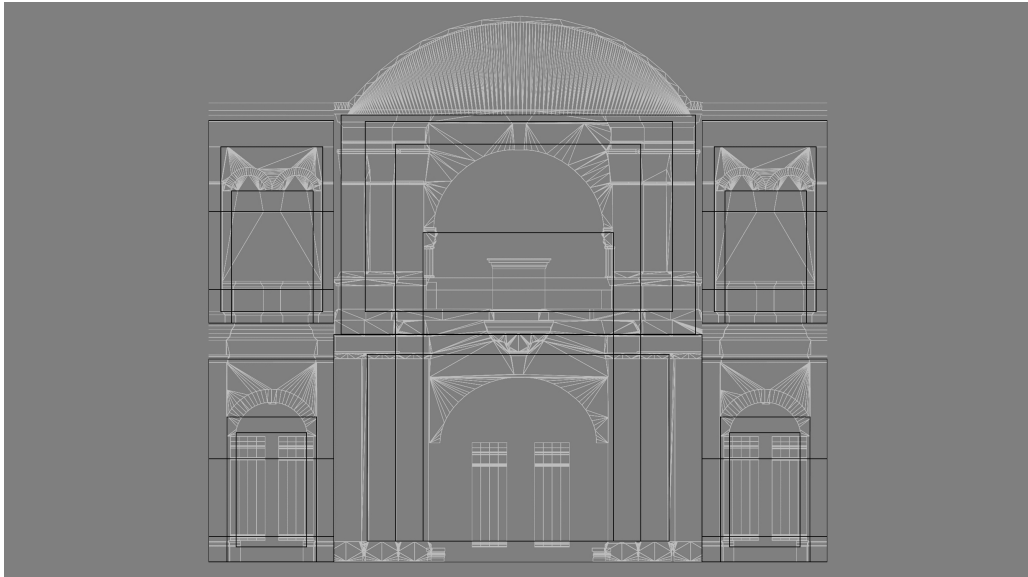
Figure 9: Singapore Art Museum with golden ratio rectangles, image by NOVAK and Ed Carter

The composition method interprets these rectangles as a graphic score, using them to dictate the timing and pitch of each note. It achieved this by scaling the proportions of the rectangles into relative frequencies, then attributing to each one the closest pitch from the A=440hz Western musical scale.

The orientation of each rectangle and "playhead" establishes the type of tone created. For example, a vertical "playhead" moving horizontally across the graphic score will trigger a sound with a short decay (e.g. xylophone) when encountering the vertical side of a rectangle, and will trigger sounds with a long decay (e.g. a glockenspiel) when passing the horizontal edges of the rectangle.

The ground floor graphic score elements trigger sounds in a lower register than those on the first floor – for example vibraphone on ground floor, and glockenspiel on the first floor. In addition to this, the positions of pillars and columns also dictate the timings of additional percussive sounds.

Unlike Practice A: "Barographic: The Lowry", the graphical scoring process was not intended for synchronised public presentation in this instance — only the audio, alongside NOVAK's projected work. As a result, IanniX's role as a tool that visualised the sequencing process was not required. Because of this, the composition process took a more manual numerical approach to the behaviour of the notional "playheads", compiling timings, pitches and relative positions in a spreadsheet, which were then transferred into Pro Tools for the production of the music.

4.2.3.4 Visual

As the projection-mapped element of the presented work at Singapore Art Museum was created by NOVAK independently of my composition process, the development of a visual manifestation of the graphic scoring process was not influenced by specific presentation requirements.

The approach taken was to create a form only showing the golden ratio rectangles observed in the architecture, which were used as the graphical basis of the composition process. This was designed to a size that could fit on a typical stand for traditional sheet music, with the intention it could be provided to musicians for live improvised performances.

The fabrication process utilised low-cost 3D printing (using a Makerbot), to create a kit of parts, which were then assembled manually. The design process created an extruded 3D form in Sketchup, which was then converted in Rhino (3D CAD software) prior to the printing process (with technical support from Paul Adamson at Sunderland University).

The aim of this approach was to examine the golden ratio rectangles in isolation, separated from the architectural form itself, in order to see if

the geometry revealed anything about the architectural context, and specifically about the architect's creative process or intent.
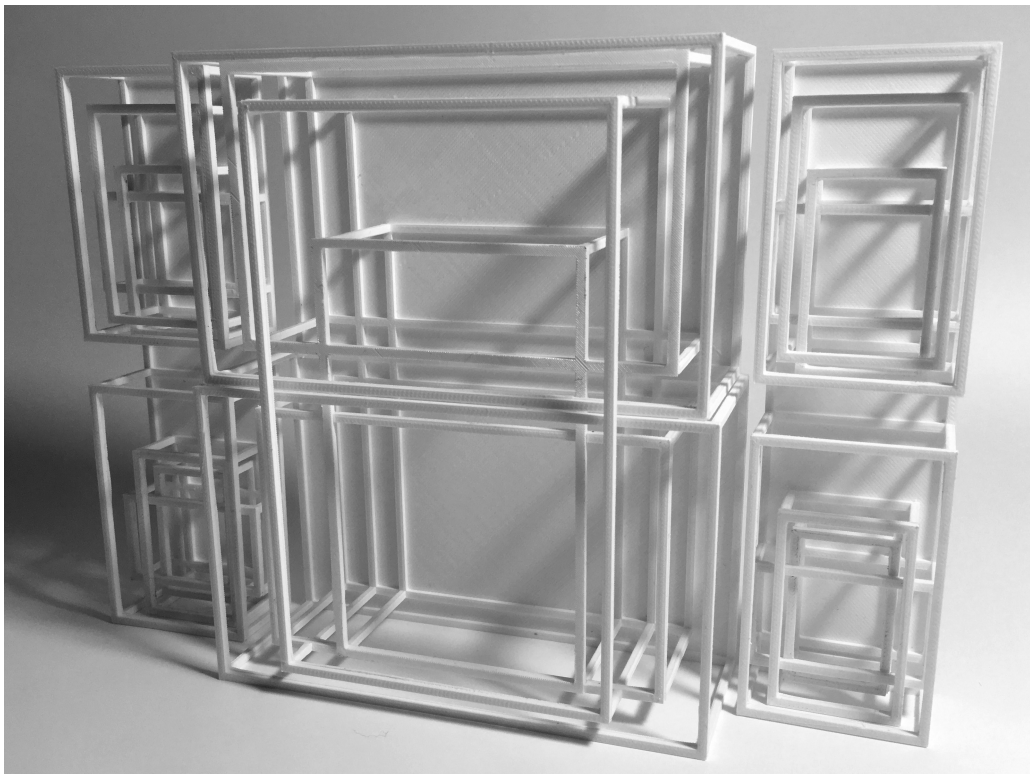
Figure 10: Singapore Art Museum 3D printed graphic score (2016) by Ed Carter

4.2.3.5 Presentation

Figure 11: "Journey" (2016) projection by NOVAK with soundtrack by Ed Carter, photo Ed Carter

The completed music composition was presented as a looped, stereo recording alongside NOVAK's projected work at Singapore Art Museum during Singapore Night Festival in 2016. The graphic score element has not been exhibited publicly, but images explaining the process formed the basis of my public talk at the National Museum of Singapore as part of the festival programme.

4.2.4 Observations from Practice B: "Journey"

"To make geometric analyses by trying to get inside the head of a long-departed architect is folly… the shapes an architect chooses are matters of fact; how he arrived at them is a matter of opinion. I don't want to go hunting for golden section rectangles.

They are too easy to find and don't mean much when found."
(Hersey, 2000: 14)

Whilst mindful of George Hersey's attitude towards this type of approach, the process led to two main observations which align with those made in response to Practice A: "Barographic: The Lowry". These relate once again to issues of scale and scaling, but also to how this type of geometric rhythmic analysis can inform and guide the creative process, by providing additional insight when creating new work in response to an architectural context.

4.2.4.1 Scale and Scalability

As observed with Practice A: "Barographic: The Lowry", the process of translation from one medium (architectural form) to other disciplines (music and 3D print) was subject to arbitrary scaling. Whilst the golden ratio rectangles retained their relative proportions, their final sizes (as presented both by the desktop 3D model, and the associated timings of their sonic realisation) were chosen on purely aesthetic grounds.

By removing IanniX from the creative process, it clarifies that this issue of arbitrary scaling is not the fault of the audio and visual digital tools per se (although they may facilitate and accelerate the process), but the result of numerical approach taken in transferring the geometry of one discipline to another.

This observation supports those from Practice A: "Barographic: The Lowry", raising issues of scale and scaling when responding to architectural context in this manner. The second area of research in this study "Scale" takes this topic forward, paying particular attention to anthropometric approaches to scale (see Practice C: "SCALE").

4.2.4.2 "Rhythmanalysis" as a tool for investigating architectural context

As seen with Practice A: "Barographic: The Lowry", observing visual and structural rhythms in the built environment went beyond merely providing an approach for creating new work, with the process itself functioning also as a tool for gaining greater understanding of the architectural context, guiding research, and possibly giving clues as to the working process of its designer.

This observation aligns with Miwon Kwon's broader analysis of the manner in which site-specific art can unveil hidden details about the social context in which it is developed:

> "Certainly, site-specific art can lead to the unearthing of repressed histories, help provide greater visibility to marginalized groups and issues, and initiate the re(dis)covery of minor places so far ignored by the dominant culture. But… the siting of art in "real" places can also be a means to *extract* the social and historical dimensions of these places in order to variously serve the thematic drive of an artist, satisfy institutional demographic profiles, or fulfil the fiscal needs of a city." (Kwon, 2002: 53)

In developing the graphic score in 2D and 3D, it became apparent that horizontal and vertical golden ratio rectangles create cross shapes on both the ground and first floor (Figure 12 and Figure 13), the proportions of which are repeated across each of the bays along the length of the building (Figure 8).
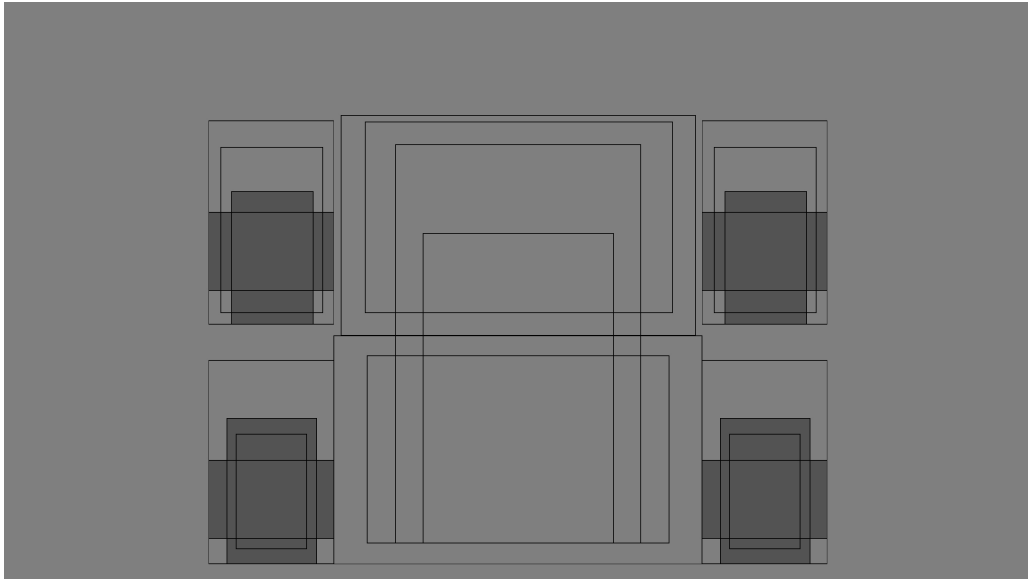
Figure 12: Singapore Art Museum graphic score with observed crosses highlighted
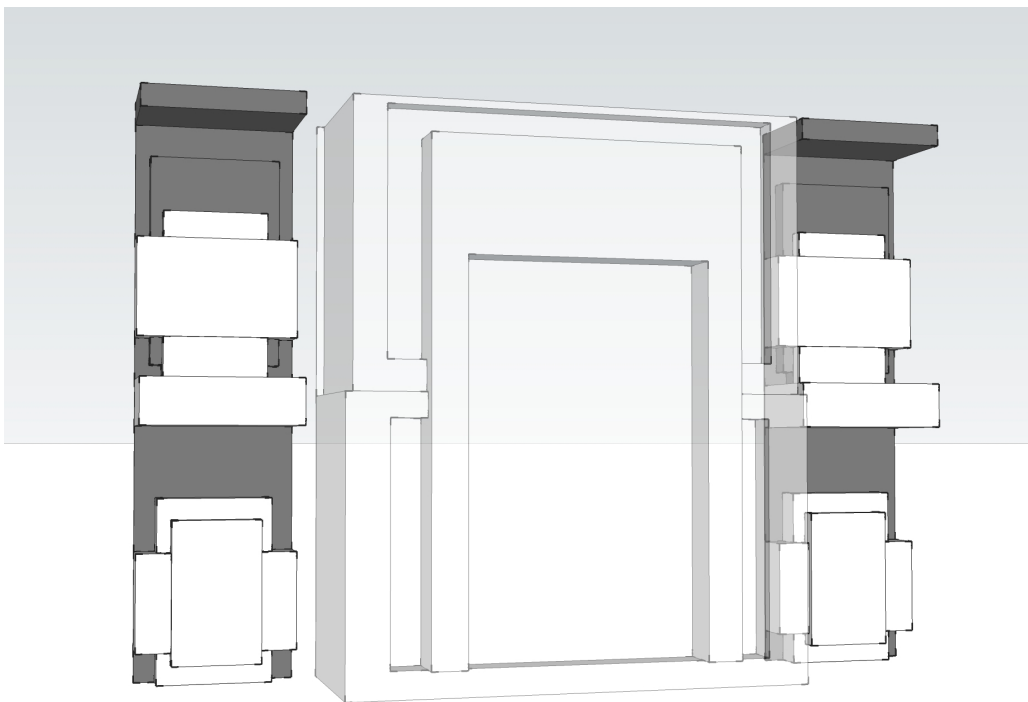
Figure 13: Singapore graphic score 3D extrusions

Prior to observing this feature, the composition process had been entirely focused on translating the golden ratio through the 2D and 3D models provided, to the exclusion of other obvious architectural details

– notably overlooking the significance of crosses mounted on the roof of the entrance area and central domed roof, and the name "St. Joseph's Institution" above the entrance.

This initiated further reading about the history of Singapore Art Museum, which revealed how the former Catholic school had been established by Father Jean-Marie Beurel in the mid-19th century on the site of the first Roman Catholic church in Singapore. The original school building was designed by Brother Lothaire Combes (completed 1867) in the style of "typical 19th century religious architecture" (Tan, no date). However, the current façade was added later, designed by Brother Michael Noctor and Father Charles-Benedict Nain (Tan, no date) – the latter has been described as "passionate about architecture… an adept draughtsman" (Pilon and Weiler, 2011: 106).

In light of this information about the architects' spiritual beliefs, and the building's religious purpose, it is not inconceivable that they might have sought to incorporate ecclesiastical iconography (crosses) within their design process. However, this interpretation is clearly speculative, and as George Hersey rightly reminds us:

> "the shapes an architect chooses are matters of fact; how he arrived at them is a matter of opinion" (Hersey, 2000: 14).

Nevertheless, the finding here once again is not to assert conclusively that the priest architects created crosses in their building design using golden ratio rectangles, or even that they explicitly used the golden ratio in their working process. The key finding from this project is simply that, as a practitioner responding to architectural context, employing "rhythm" as an analytical tool clearly shaped the direction of the creative process, guiding research, and thereby directly contributing to a broader understanding of the architectural context.

This observation seems in-keeping with the thoughts of George Hersey (in spite of his reservations mentioned previously), who also highlights the manner in which hidden connections can be uncovered through observing the geometry of architectural form:

> "the analysis of geometrically constructed plans and elevations can reveal connections between architectures that, from a strictly stylistic viewpoint, seem unrelated. In other words, geometry brings together things that up to now have been considered too separately. Geometry – both the traditional kind and its modern extensions – shows affinities between musical chords and architectural moldings, and between the epicycles of the cosmos and those of gears and chapels. It can, as noted, express unsuspected kinships between Borromini and Wright, between Robert Fludd and Le Corbusier." (Hersey, 2000: 223)

4.2.4.3 Interior vs Exterior

It is important to note that this piece focused purely on external architectural features, and to an even greater extent than "Barographic: The Lowry". As a result, the second section of research "Scale" concentrates on the experience of interior space.

5 Scale

5.1 Contextual review

One of the key issues raised by the "Rhythm" practical research projects was the significance of scale, not only to architecture and music as independent disciplines, but also in terms of the suitability of quantitative mechanisms used in translating between art forms. Drawing on examples from architecture, music, and sculpture, this section works towards developing a creative approach that considers issues regarding arbitrary scaling, whilst continuing to encompass both numerical and aesthetic methods in responding to subjective experience of architectural context. These ideas then informed the nature of the practical research projects documented in section 5.2.

5.1.1 Scale or size?

The terms "scale" and "size" are often used interchangeably (Wells, 2015: 2) in descriptions of relative dimensions, or perceived levels of significance. However, Rachel Wells offers some useful distinctions between the two in her research on contemporary sculpture, which are particularly relevant to the ambition for this research to engage with architectural contexts through both qualitative and quantitative means.

Wells' approach draws on the work of Henri Bergson (Wells, 2013: 5), arguing that "the distinction between scale and size is applicable to that noted by Bergson between the differences of 'quantity' and differences of 'quality'" (Wells, 2013: 6). Wells goes on to suggest that:

> "Size, as an attribute of an object, is bound up with its difference in nature from other objects, whereas a measurement of scale focuses upon a difference in degree between at least two similar objects. This fundamental distinction between size and scale is

crucial to an understanding of the different effects that each causes." (Wells, 2013: 6).

The notion that scale can only describe differences between two similar entities is significant, as it suggests that architectural scale can only be considered in terms of the relationship between different buildings, or perhaps even between the same *type* of building (homes, car parks, theatre spaces etc.), and not in relation to any other features in the surrounding landscape such as mountains, trees, vehicles, or people.

This is broadly in-keeping with Eugene Raskin's comments on architectural scale, which also suggest a building's scale can only be perceived in relation to other buildings:

> "a given building has *no inherent scale quality of its own*. Its scale effectiveness lies entirely in the relationship between its scale and the complex of other existing architectural work." (Raskin, 1954: 50)

One of the interesting aspects of Wells' approach is that the human body can therefore only be used as a measure of scale in relation to other humans, and certainly not as a tool for interpreting architectural scale:

> "the body is more removed from the perception of scale than it is from the perception of size (Wells, 2013: 15)… The awareness of scale is a function of the comparison made between one object, as constant, and another similar object of a different size... While size is a measurement in relation to the constant of one's own body, scale distances one's body to a secondary position." (Wells, 2013: 17),

Taken to its natural conclusion, this interpretation of scale and size raises two significant issues for the purposes of this research. Firstly, it suggests that any use of the human body as a tool for interpreting architectural context would be observing relative size, rather than relative scale. Secondly, and more significantly, it would therefore also mean that using the human body as a tool for interpreting architectural context constitutes a qualitative approach, as opposed to a quantitative approach based on a relative scale between two similar objects.

With this in mind, the following practical research projects consider anthropometric approaches to engaging with architectural contexts.

The third practical project (Practice C: "SCALE") places a set of abstracted human forms in a gallery space, providing a fixed measurement to which participants can relate their own personal *scale*, and thereby theoretically experience the manner in which the work responds to its architectural context in quantitative terms. The fourth practical project (Practice D: "My Modulor") uses the participant's own body *size* as the basis of the work, thereby theoretically enabling them to directly experience the work's response to its architectural context in qualitative terms.

5.1.2 Architectural and musical scale

Outside of architecture and music, interpretations of 'scale' arguably have fewer constraints. For example, sculptors Barbara Hepworth and Henry Moore both suggested scale could be independent of physical size (Wells, 2015: 1), using the term as a subjective, qualitative measure of form, equally applicable to the miniscule and colossal.

However, the standard methods and terminologies associated with both architecture and music fail to afford quite this degree of flexibility. This is perhaps due to the fact that each discipline widely uses "scale" to

describe a fixed mathematical process that plays a central role in creating and communicating the work. For example, any ambiguity concerning building from a "scale drawing", or the transposition of a "musical scale" for a performance, is likely to lead to undesirable, or at least unpredictable, results.

> "It is also useful to speak of *scale* in describing an art work so long as the term is not confused with its specific musical meaning – as the consecutive ordering of the basic pitch structure; but even then this restricted use of the word is not inconsistent with the larger meaning if one compares a music scale to the scale on a ruler or yardstick, or even the scale of a map: it is the basic set of proportions along which the art object is laid out." (Rowell, 1984: 27)

This does not mean that notions of architectural and musical scale are purely quantitative, as qualitative experience and perception are fundamental to our interactions with both disciplines. It does, however, suggest that traditional approaches to architectural and musical scale have been greatly informed by numerical principles.

> "Architecture and music both have an investment in the issue of scale. In building we think of scale as pertaining to a successive and consistent alteration in size. The metaphor is that of climbing a ladder. Things get smaller or larger to view as you ascend or descend a ladder of series of steps (*escalier*). A musical scale is similar. Ascending the musical scale, accomplished by successively shorter strings or tubes, produces sounds that are of higher pitch. In both architecture and music, the use of scale is regular, calculable and predictable" (Coyne, 2011: 137).

However, alongside this mathematical basis, "scale" is often prefixed with a qualitative descriptor, such as "right/wrong", "in/out", or

"good/bad". Although a sense of scale can be described in numerical terms, the effectiveness of its implementation is still very much open to subjective interpretation. Therefore, it can be argued that the key to presenting the "right scale" (Adler et al., 2011: 1) lies in how successfully its relative scale is communicated, in order that it can be interpreted appropriately:

> "good scale" has as its referent, "scale that is correctly interpreted" while "bad scale" boils down to "scale that is erroneously interpreted". No building is ever "out of scale" (a misleading phrase). Every building is actually the size that it is... It is in the process of interpretation that the trouble, if any, arises."(Raskin, 1954: 40)

This therefore raises the question of what provides us with a sense of architectural scale? How do we interpret scale as right, or wrong? Raskin again provides a logical explanation for this, in that we are constantly interpreting scale as an abstraction of the object, rather than dealing with the object itself:

> "When you look at an actual building, you are still not seeing real dimensions. You see an image on your retina cast there through the lens of your eye. This image will vary in size depending upon your distance from the structure. Between the image and the reality there is a scale relationship. You *see* the dimensions of the image, but you *think* the dimensions of the building. In other words, whether you are looking at a drawing of the building or at the building itself, you are always looking at a scale picture."
> (Raskin, 1954: 38-39)

The concept of scale being interpreted as "right" or "wrong" brings to mind to Rem Koolhaas' provocations concerning the "purely quantitative" approach taken to what he defines as "Bigness" in

contemporary architecture, and how such enormous structures can be disconnected from their wider context:

> "Fuelled initially by the thoughtless energy of the purely quantitative, Bigness has been, for nearly a century, a condition almost without thinkers, a revolution without programme… Issues of composition, scale, proportion, detail are now moot…Bigness is no longer part of any urban tissue… its subtext is fuck context" (Koolhaas et al., 1998: 499-502)

This attitude to scale highlights the way in which an architectural context reaches beyond the envelope of the building itself, and that within this broader context, the size/scale of a structure can be intentionally at odds with its local environment. Therefore, in developing creative work that responds to an architectural context, it is critical to look not only at the fabric of the building, but to its broader geographical and social surroundings, and the connections (or otherwise) between them. This idea is taken forward in the third section of this research, looking at approaches to "liminality".

5.1.3 Anthropometric scale

Although Gerald Adler describes the architectural debate concerning human form as a basis of measure as "the big elephant in a diminutive room" (Adler et al., 2011: 2), it offers a useful framework for this research because, like Henri Lefebvre's use of "rhythm", Wells' interpretation of the body as a measure bridges the qualitative and the quantitative, whether applied to scale or size.

Human scale is understandably a critical aspect of architectural design and theory, with Jeremy Till describing it as:

> "1:1 is the scale of the personal, the intimate, the human." (Till, 2006: 2)

However, there are also many examples of human scale being used quantitatively as a basis of sonic artworks:

> "I like to work with sounds that resonate naturally in the site, the ones that fit the place. The sounds I choose are usually three to nine feet long, and very full and rounded. I think of them as being of human scale." (Brewster, 2002: 104)

According to Lefebvre, the Rhythmanalyst first listens to their own body, which "serves him as a metronome" (Lefebvre, 2013: 29), providing a measure to which all other temporal and spatial rhythms can be compared. Whilst Lefebvre approaches the issue from a slightly different perspective, the use of the human body as a measure is long-standing, and deeply ingrained in contemporary culture. This is demonstrated by the number of human-based measurements in use around the world today, including the inch (thumb), span (hand), cubit (forearm), foot, and fathom (both arms and hands outstretched).

Approximately 2000 years ago in his "Ten Books on Architecture", Vitruvius described his observations on human proportions, not as fixed measurements, but as fractions of a person's full height, including head (one eighth), face length (once tenth), foot (one sixth), forearm and chest breadth (one fourth), and even expressing ideal proportions for facial features (Vitruvius Pollio and Morgan, 1960: 72). Vitruvius recommended that architectural form should also reflect these proportions:

> "since nature has designed the human body so that its members are duly proportioned to the frame as a whole… in perfect buildings the different members must be in exact symmetrical

relations to the whole general scheme" (Vitruvius Pollio and Morgan, 1960: 73).

The long-term influence of this model is significant, with one notable example being its visual realisation over 1400 years later in the form of Leonardo Da Vinci's ubiquitous "Vitruvian Man" illustration, which he developed alongside mathematician Luca Pacioli (Heydenreich, 2018).

Moving forward to the mid-twentieth century, the esteemed architect Le Corbusier (Charles Edouard Jeanneret) wrote "Le Modulor", in which he set out the basis of a scale that he considered to be a "universal harmonious measure" (Le Corbusier, 1961: 177). His approach proposed using the golden ratio (1:0.618) to divide up a human form, so like Vitruvius, Le Corbusier was attempting to "reconcile biology with architecture through the medium of geometry" (Ostwald, 2001: 146).

Le Corbusier's approach raises numerous issues regarding the use of the human body as a measure, and as such is used as the basis for the practical research projects that follow. Michael Ostwald provides an eloquent summary of "Le Modulor", saying that:

> "Le Corbusier's Modulor represents a curious turning point in architectural history: In one sense it represents a final brave attempt to provide a unifying rule for all architecture; in another it records the failure and limits of such an approach." (Ostwald, 2001: 146)

5.1.4 Le Modulor

> "More than these thirty years past, the sap of mathematics has flown through the veins of my work, both as an architect and painter; for music is always present within me." (Le Corbusier, 1961: 129)

Throughout "Le Modulor", Le Corbusier makes frequent references to music (and particularly harmony), in his quest to achieve a "universal harmonious measure" (Le Corbusier, 1961: 177), and his approach to the relationship between the disciplines is overtly quantitative:

> "Music, like architecture, is time and space. Music and architecture alike are a matter of measure." (Le Corbusier, 1961: 29)

It is perhaps no coincidence that Le Corbusier chooses similar language to that of Robert Fludd, who 300 years previously used architectural analogies throughout his "Temple of Music", in "Utriusque Cosmi". On music being both spatial and temporal, his phrasing is remarkably similar to Le Corbusier's:

> "[Instrumental music] is either *positional*… or *durational* … It is therefore evident that harmonic music is a discerning of measurement" (Fludd and Hauge, 2011: 43)

Like Fludd, and Vitruvius before him, Le Corbusier was working in an era when mathematics was perceived as a "potential source of universal truths" (Ostwald, 2001: 1), and as such, it is unsurprising that he chose the golden ratio (Φ, or 1:0.618…) and its perceived association with nature as the basis of a proportional measuring system for the human body.

"Le Modulor" was devised in part to address a practical problem (the inconsistencies between imperial and metric measurements), but it failed to achieve the global adoption that Le Corbusier desired. To some extent, this was due to inconsistencies in the application of the theory, which left "Le Modulor" open to criticism in two critical areas – the approach to the human body, and the mathematics that underpinned the scale:

> "The maddening aspects include a complete lack of consistency in geometric conventions or descriptions and a blatant ignorance of actual human proportions." (Ostwald, 2001: 147)

One of the conceptual problems was that Le Corbusier seems undecided as to whether mathematics controls nature, or if it is a mechanism devised by humans for understanding natural phenomena. This apparent dichotomy is evidenced at various points throughout "Le Modulor":

> "Nature is ruled by mathematics, and the masterpieces of art are in consonance with nature; they express the laws of nature and themselves proceed from those laws. Consequently, they too are governed by mathematics, and the scholar's implacable reasoning and unerring formulae may be applied to art." (Le Corbusier, 1961: 29-30)

> "Mathematics is the majestic structure conceived by man to grant him comprehension of the universe." (Le Corbusier, 1961: 71)

As Richard Padovan says: "The shortcomings of the *modulor* originate, I suspect, at the most fundamental level, from Le Corbusier's failure to resolve the conflict in his own thinking between the two viewpoints." (Padovan, 1999: 341)

However, a more practical problem with "Le Modulor" is the fact that it is anything but the universal measure that Le Corbusier claimed. The decision-making process for selecting the height of "Modulor Man" was entirely arbitrary. When describing the decision-making process, Le Corbusier quotes a colleague (Py) as having suggested that:

> "The values on the "Modulor" in its present form are determined by the body of a man 1.75m in height. But isn't that rather a

French height. Have you ever noticed that in English detective novels, the good-looking men, such as the policemen, are always six feet tall?" (Le Corbusier, 1961: 56)

As a result, the scale was altered, and subsequently was only suited to tall (6') males, and failed to cater for the rest of the global population that fail to meet those criteria. It is this arbitrary process, and its subsequent inflexibility that informs the practical research projects documented later in this section (Practice C:"SCALE" and Practice D: "My Modulor").

In Nadia Mounajjed's research into the body-architecture relationship in the digital age, Mounajjed compares Le Corbusier's "Modulor Man" with an intentionally similar figure from Rafael Lozano-Hemmer's work "Body Movies":

> "Not only do the two bodies look the same but they also represent the notion of body as measure. Nevertheless they take radically different approaches. In Le Corbusier's case, the body is a measure of commensurability; Le Modulor became a measure of prefabrication allowing for efficiency and proportion in house production. On the other hand, with Lozano-Hemmer, the body is also seen as a measure, but this time, it is the body of user put in action. And what matters here the most are the sensibilities, movement and interactivity of the body as they become the measure of relationality in architecture. (Mounajjed, 2007: 166)

As part of her discussion on the changing perception of the body-architecture relationship, Mounajjed here differentiates between the role of the body as a fixed, homogenising, quantitative measure of space, as opposed to a mobile, personal, qualitative measure of experience.

These two perspectives directly feed into the process underpinning the practical works documented below (Practice C: "SCALE" and Practice D: "My Modulor").

As an example of how "Le Modulor" is still influencing contemporary practice, Radaslov Zuk's research "Three Musical Interpretations of Le Corbusier's Modulor" (2013) also questions Le Corbusier's methodology with regards to music harmony. He proposes three variations of the scale, adjusted to create Western Chromatic, Major and Minor musical scales, and as also seen in Practice C: "SCALE", Zuk introduces a scale that relates to a female figure (Zuk, 2013: 155). However, it appears this approach removes the golden ratio scale that was central to Le Corbusier's initial concept.

As previously stated, one aim for this research is to maintain both the qualitative and the quantitative in responding to architectural contexts, and Louis Kahn's approach to the "measureable" and the "unmeasurable". Perhaps Kahn offers the most poignant dismissal of Le Corbusier's quantitative approach, particularly as he was such a huge influence on Kahn's own work (Lobell and Kahn, 2008: 52):

> "There is nothing about man that is really measurable. He is completely unmeasurable. He is the seat of the unmeasurable, and he employs the measurable to make it possible for him to express something." (Lobell and Kahn, 2008: 14)

5.1.5 Digital scale

As observed from the practical research projects in the "Rhythm" chapter (Practice A: "Barographic: The Lowry", and Practice B: "Journey"), digital tools may not be the cause of arbitrary approaches to quantitative scaling, but they do have the capacity to facilitate, simplify, and accelerate the process. John Maeda has raised issues caused by

the "absence of a single default scale" in digital space (Maeda, 2000: 142), Hersey has suggested that CAD software "effectively lets the machine do the thinking", circumnavigating "consciously applied geometry" and automatically providing "quantities and values for scale" (Hersey, 2000: 204); and Coyne has noted the significance of computer software in simplifying the calculations required for transposition of scale in both architecture and music (Coyne, 2011: 137).

From a philosophical perspective, Rachel Wells references Paul Virilio's book "Open Sky", in which he puts forward an argument that digital communication results in a "loss of the life-size" (Wells, 2013b: 210) by disrupting the traditional connection between distance and time. This relationship between digital technologies and "life-size" has a direct connection to issues surrounding contemporary representations of anthropometric scale, which underpin the practical research projects documented later in this chapter.

However, architect Nadia Mounajjed perhaps describes a more tangible impact of digital technologies on our perception of the human form. Mounajjed places her own research on the body-architecture relationship within the historical context of anthropocentric practice, noting that in multi-dimensional virtual environments, our experience is "often characterized by the denial of a body" (Mounajjed, 2007: 46), highlighting the significance of digital tools in moving away from traditional notions of anthropometric scale.

5.2 Scale: Practical research projects

The following section documents a further two of my own practical projects which build on observations from the work described in the previous chapter on "Rhythm", specifically responding to perceived issues concerning arbitrary approaches to scaling, and exploring architectural contexts from an interior (rather than exterior) perspective.

Whereas the previous projects were tailored to a specific building, these works focus on the human body as a measure, and some of the issues associated with this as a design methodology. The pieces use an anthropometric scale to highlight the subjectivity of our relationship with the built environment. As such, they can be thought of as transferable, spatial-temporal tools for exploring our surroundings – something that physically reacts to architecture, rather than consciously analysing its geometric form. The projects reference Le Corbusier's "Modulor" system to highlight problems of fixed scales of measurement, using it to realise a sonic representation of the human form – which in a virtual environment might be considered a sonic avatar.

As before, a brief overview of the architectural context is provided for each project (and the commissioning context where relevant), followed by a description of the creative process, and any subsequent observations.

5.2.1 Practice C: "SCALE"

5.2.1.1 Context

Practice C: "SCALE" was commissioned and presented by Sculpture30 festival for exhibition in the gallery space at Gateshead Central Library (UK) in March 2016.

The gallery space is part of a 1970s extension to Gateshead's Central Library (built 1925), with contemporary wooden floors, a suspended ceiling, and a large partition wall that blocks light from the floor-to-ceiling windows that fill one side of the gallery space. However, the work was not created specifically for these surroundings, but designed to *reflect* its surroundings wherever it may be exhibited. The works looks at our subjective experience of architecture, represented through anthropometric scales of measurement.

Therefore, this work can be seen as using its architectural context as a tool for examining perception and application of human scale in relation to the built environment. Equally, it can be seen as using human scale as a tool for interrogating an architectural context.

5.2.1.2 Process and presentation

A starting point for creating the work was Le Corbusier's "Modulor" scale (Le Corbusier, 1961), in which he attempted to consolidate an anthropocentric design methodology with the proportions of the golden ratio. His aim was to create a "universal harmonious measure" (Le Corbusier, 1961: 177), but as previously described in section 5.1.4, the fixed scale was actually tailored specifically to the body of a six foot tall male.

Regardless of the significance of the architecture realised using this approach, as a system of measurement "Le Modulor" is clearly far from universal. If anything, it serves as a reminder of the extent to which the industry is male-dominated[2], and the societal implications this can have — with the potential of a fixed anthropometric scale to create a built environment that only meets the needs of a small proportion of its inhabitants who happened to fit the restrictive gender/height parameters considered to be "universal" by Le Corbusier.

In order to highlight this issue through the work, measurements from Le Corbusier's scale (based on his idealised six foot male figure) were interpreted as wavelengths and realised as sine waves — with sculptural and sonic forms created from the same numerical source.

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[2] Whilst 44% of architecture students in the UK are female, women account for less than 13% of RIBA chartered architects (Duncan, 2013), and only around 24% of Arb registered architects (Smith, 2016). What are the implications of these statistics on architectural structures whose user-base is almost 51% female? ("2011 Census - Office for National Statistics," 2011)

Then the process was repeated, but scaled down to represent an equally arbitrary "female" form (measuring five feet and ten inches).

The two physical and sonic representations of the original and reduced scales were then combined into a single piece as a completely unrepresentative "universal couple", expressing not only issues of standardised expectations relating to physical size, but highlighting how the implications of a universal measure extend to the proliferation of other social hierarchies such gender, sexuality, and beyond.

By creating two similar forms of slightly differing sizes, the intention was that the arbitrary scaling between them would produce unpredictable and dissonant tones, representing the disjointed results of building to a fixed anthropometric scale for a non-standardised human population.

The completed piece was then repeated, scaled again (at a ratio of 1: 0.618, referencing "Le Modulor"'s application of the golden ratio), and presented together to reiterate the potential issues of arbitrary scaling in translating architectonic principles.

Documentary video of the installation is available online (https://vimeo.com/340193968).

5.2.1.3 Sonic process

> "The MODULOR is a scale. Musicians have a scale; they make
> music, which may be trite or beautiful". (Le Corbusier, 1961: 5)

Le Corbusier's draws numerous comparisons between "Le Modulor" and musical / sonic scales and harmony (Le Corbusier, 1961: 15, 16, 29, 74), including the 12-note tempered scale used in Western music (Le Corbusier, 1961: 16). To maintain this frame of reference in the new work Practice C: "SCALE", only the first twelve measurements from "Le

Modulor" are utilised within the piece. This also has the result of keeping all of the sonic frequencies within the range of human hearing. Tim Sheridan describes a similar approach, using wavelengths as a form of measure in his own sonic responses to architecture:

> While buildings are larger than conventional musical instruments, the wavelengths of audible sound from 17mm at 20KHz to 17m at 20Hz easily overlap the bulk of instruments with architectural spaces." (Sheridan, 2007: 185)

The first stage of development involved interpreting the "Modulor" measurements as wavelengths (Figure 14) and converting them to sonic frequencies, thereby creating a new musical scale. This was then replicated for the scaled "female" measurements, as shown in Table 1.
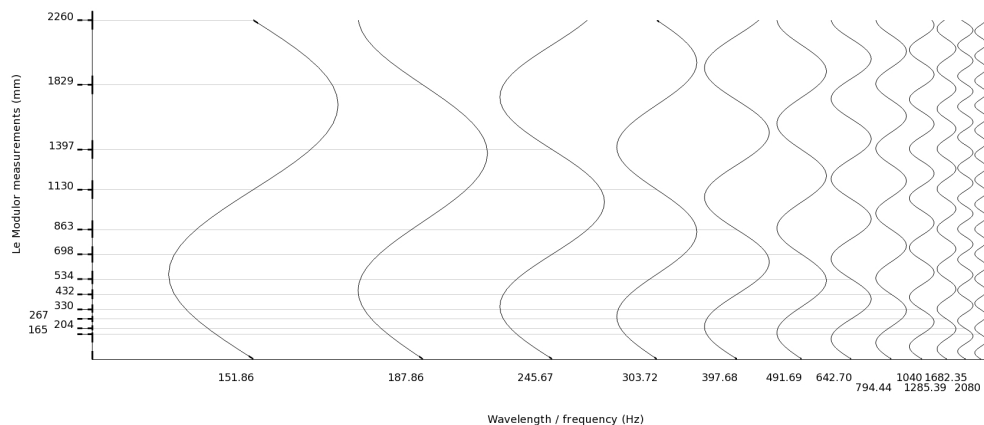
Figure 14: Le Modulor measurements as sine wavelengths

Modulor 6ft "MALE" (mm)	Wavelength freq (hz)		Modulor scaled 5ft10 "FEMALE" (mm)	Wavelength freq (hz)
2260.00	151.86		2196.72	156.23
1829.00	187.64		1777.79	193.05
1397.00	245.67		1357.88	252.75
1130.00	303.72		1098.36	312.47
863.00	397.68		838.84	409.14
698.00	491.69		678.46	505.85
534.00	642.70		519.05	661.21
432.00	794.44		419.90	817.33
330.00	1040.00		320.76	1069.96
267.00	1285.39		259.52	1322.42
204.00	1682.35		198.29	1730.82
165.00	2080.00		160.38	2139.92

Table 1: Le Modulor "male" measurements and arbitrarily scaled "female" set

Figure 15 shows the wavelengths overlaid in two sets, with the original on the left, and the scaled "female" set on the right. The image demonstrates the direct connection between the sonic waveforms and the sculptural form, and their mutual relationship to Le Corbusier's "Modulor" measurements.
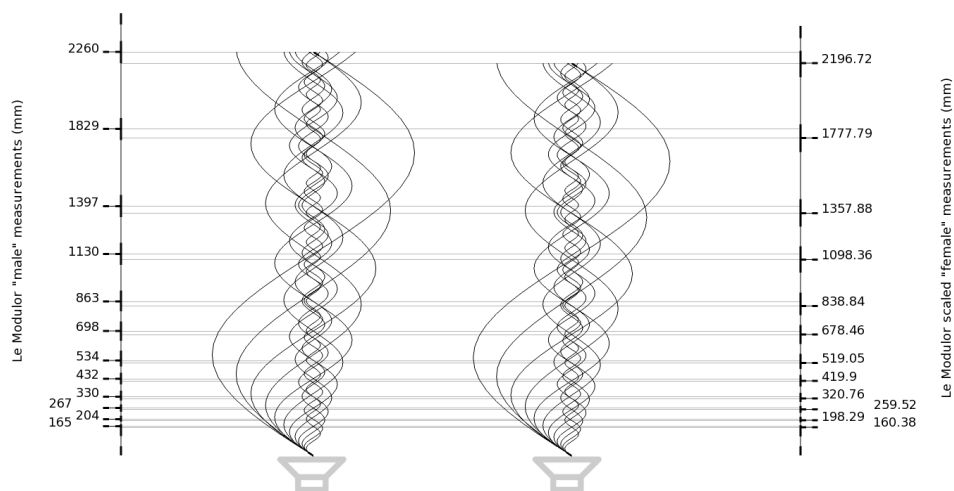
Figure 15: Le Modulor "male" measurements as overlaid sinewaves (left) and arbitrarily scaled "female" sinewaves (right)

"There are compelling mathematical and physical reasons for employing sine waves [single frequencies] as the foundational units of analysis for sound waveforms" Lamont Young (LaBelle, 2006: 75)

The reasoning for using sine waves concerns their behaviour when encountering architectural space, as wavelengths of differing lengths will create different sonic experiences, directly relating to the proportions and materiality of their surroundings. Lamont Young notably used this phenomenon using single tones to create standing waves in the "Dream House" (LaBelle, 2006: 75). Using multiple tones creates a more nuanced effect, with phase relationships between each sinewave constantly changing in response to the other frequencies produced, and the reflections created by the space around them:

"The sound-space interplay is inherently conversational in so far as one speaks to the other – when sounds occur, they are partially formed by their spatial counterpart, and spatial experience is given character by the eccentricities of sounds events." (LaBelle, 2006: 149)

The sequencing of the audio component also utilises measurements within the "Modulor" system. Each set of waves has a single speaker associated with it. This speaker only plays the frequencies associated with that human form (in a randomised sequence), and the time delay between each note being triggered is dictated by the largest measurement in the set (2260 and 2196.72 respectively), which is applied numerically in milliseconds (see the [metro] functions in the Pure Data patch shown in Figure 16).
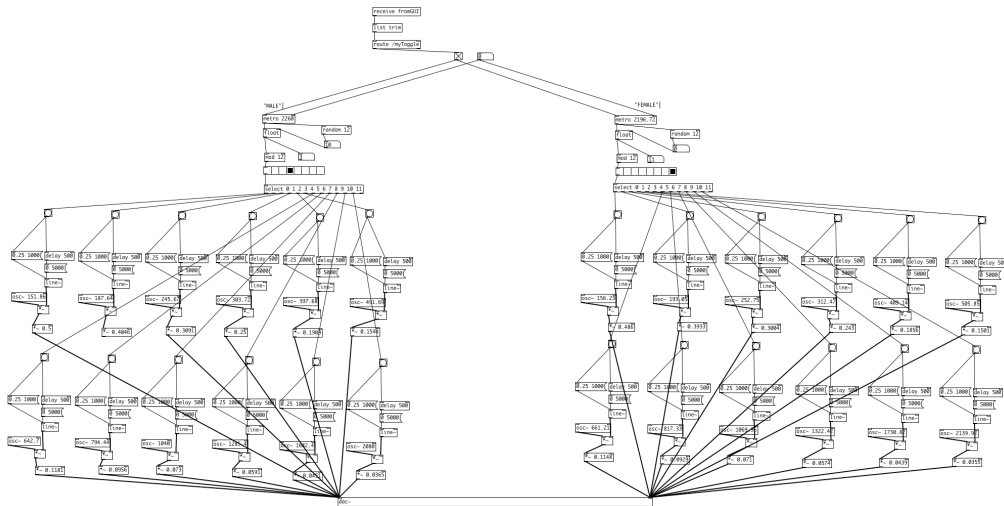
Figure 16: Pure Data software patch

When played together, the two sets of sinewaves create a sonic dissonance, which, along with the variation in tempo, reflects the disconnect between the "male" and "female" scales.

To emphasise this effect, and return to the issue of arbitrary approaches to scaling, the entire process is duplicated, but with every element once again scaled by the golden ratio (0.618).

The sonic aspect of the work was produced using Miller Puckette's open source visual programming environment Pure Data Vanilla. For the presentation, the MobMuPlat app was used as a wrapper to allow Pure Data patches to run on an iPhone and an iPad, which played back the audio through amplifiers and speakers mounted in each of the bases.

5.2.1.4 *Sculptural process*

The vast majority of the sculptural form was predetermined by the process of developing the sonic elements (described above). In terms of the design and fabrication process, sine waves were drawn in CAD software Sketchup using the Curve Maker and Taper Maker plugins.

These were exported and edited in Inkscape, with final edits and cutting templates completed in VCarve (with technical support from Carl Gregg at Fablab Sunderland). The two forms were then cut into 30mm and 12mm plywood (for the full size and scaled versions respectively), using a Shopbot CNC machine. The final version is shown in Figure 17.

3D printed maquettes were also developed (with technical support from Paul Adamson) to explore the potential of creating a twisting three-dimensional iteration of the sculptural piece (Figure 18). Due to budget and timescale, this approach was not realised, but it further demonstrates the scalability offered by digital tools, regardless of how resizing may undermine the intended concept (which again relates to "Modulor's" attempt to dictate a standardised human scale).

Figure 17: "SCALE" (2016) by Ed Carter, photo by Ed Carter
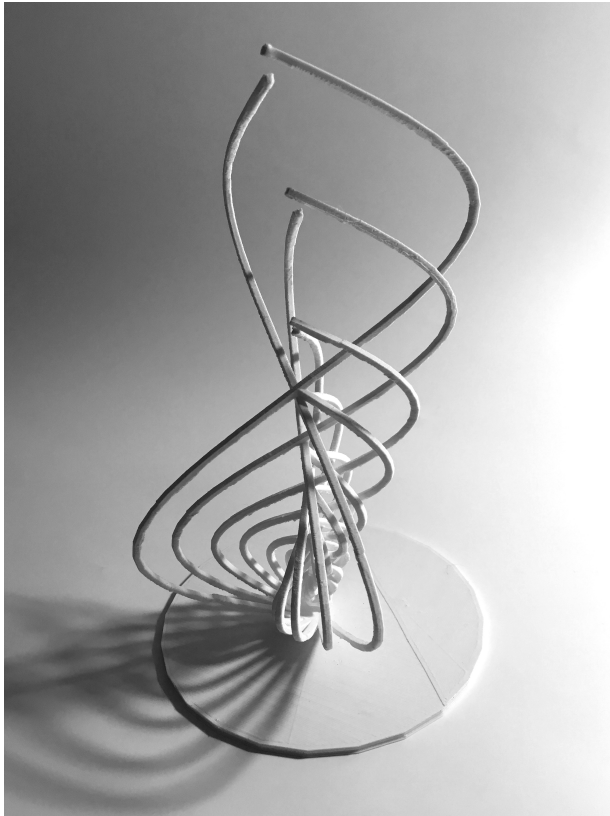
Figure 18: 3D printed maquette of "SCALE" variant, photo Ed Carter

5.2.2 Observations from Practice C: "SCALE"

A central research ambition for this project was to create a piece of work that explored arbitrary scaling by incorporating a fixed scale, and resizing the scale to observe its aesthetic effects. The aim was to use the mismatch of results (e.g. sonic dissonance) to reflect potential societal impacts of employing fixed scales of measurement – thereby evidencing the fact they cannot be universal, as Le Corbusier suggested.

The main observation was how this particular approach still placed audiences external to the relationship between the body (as represented by static sculptural forms and sound waves of matching lengths) and its architectural surroundings. In light of this observation, the subsequent piece of work (Practice D: "My Modulor") adapts this approach to respond directly to an audience member's own body,

thereby creating a direct relationship between the participant's body and their aesthetic experience of the architectural context.

5.2.2.1 Scale & Personalisation

One of the issues observed in the previous practical projects (Practice A: "Barographic: The Lowry" and Practice B: "Journey") concerned scaling when using quantitative methods to translate from one artistic discipline to another, particularly noting the "absence of a single default scale" when utilising digital tools. (Maeda, 2000: 142)

Practice C: "SCALE" employed Le Corbusier's "Modulor" system to demonstrate that, even when intended as overtly anthropocentric, a fixed scale such as this is far from universal.

As audience members encountered the work, they would see and hear Corbusier's idealised human proportions (and variations thereof), with the sonic component "sounding out" its architectural surroundings, and thereby being acoustically informed by them. However, the audience members themselves remained external to the process. The sounds did not relate their own physical form in the space, unless their height happened to match one of the scales presented in the piece.

In response to this, the next practical research project Practice D: "My Modulor" continues with the notion of using a human scale of sinewaves as a tool to explore interior architectural spaces, but employs digital and mobile technologies in an attempt to tailor the experience to each audience member. The aim of this process was to augment the participants' personal interaction with their environment via their "sonic avatar".

5.2.3 Practice D: "My Modulor"

5.2.3.1 Context

In response to observations from Practice C: "SCALE", Practice D: "My Modulor" continues the theme of using an anthropometric scale to create soundwaves whose acoustic behaviours respond to their architectural surroundings. The aim for this iteration of the work was to reference our subjective experience of architectural space by tailoring the sonic scale to each participant's own proportions.

Utilising mobile and wearable devices, the participants' physical movement around the space is actively encouraged. This not only allows them to "sound out" the space with sound waves relating to their own size, but also adds another layer of personal spatial and temporal interactions to the architectural experience.

Practice D: "My Modulor" was not created for a specific architectural context, but was developed as an independent and transferable tool whose outputs are shaped not only by the architecture in which it operates, but also by the person that is experiencing the space, and the spatial and temporal journey they choose to explore their surroundings.

Observations from Practice D: "My Modulor" include the fact that, despite being fundamentally a quantitative creative process, the actual method of engaging with the architectural context is purely qualitative (once the participant has input their height measurement), thereby using the numerical method to create an aesthetic experience. The observations also acknowledge the essential role of affordable, mobile, digital tools to enable this type of personalised experience. Finally, the issue is raised of only addressing interior space, and how architectural context actually reaches far beyond the material fabric of the building.

5.2.3.2 Process and presentation

Practice D: "My Modulor" was developed as an exploratory piece, building on the observations behind Practice C: "SCALE". To date, the work has only been tested privately, without any public presentation, and the observations are made on this basis.

Where a physical structure was created to represent the human form in Practice C: "SCALE", this was not required in Practice D: "My Modulor", as the participants' own bodies provide the visual and physical reference for the scale that underpins the sonic aspect of the work.

As such, the sculptural aspect of the previous work (Practice C: "SCALE") is replaced by wearable technology, which allows the participants to move freely, whilst emitting their tailored sonic scale (or sonic avatar) from the appropriate point in the space (head height) to augment the participants' experience of their architectural surroundings.

5.2.3.3 Sonic process

The sonic aspect of Practice D: "My Modulor" is an adaptation of the Pure Data patch created for Practice C: "SCALE" creating a series of sine waves whose wavelengths reflect the measurements in Le Corbusier's "Modulor" system. The main addition is the ability to scale all of the wavelengths and rhythms proportionally, by inputting a height value for the participant.

This can be seen in the context of Henri Lefebvre's anthropocentric emphasis for his approach, in which he places bodily rhythms at the centre of "Rhythmanalyisis":

"He listens — and first to his body; he learns rhythm from it, in order consequently to appreciate external rhythms. His body serves him as a metronome." (Lefebvre, 2013: 29)

The interface was updated to incorporate this element, again using the MobMuPlat app to allow the patch to run on iPhones for convenience and mobility (Figure 19). Using the Audiobus app to route the sound, the output of each device is sent wirelessly to a small battery-powered speaker, paired via Bluetooth.

5.2.3.4 Wearable process

To allow participants to move freely whilst emitting their personalised version of the "Modulor" musical scale, each speaker is mounted on a hard hat. This approach was chosen for a number of reasons, with a primary aim being that the sound waves produced should relate directly to the height of the participant.

The front-facing speaker mount adds a degree of directionality to the sound, which naturally relates to the direction the participant is facing, making a connection between their visual experience and their sonic exploration of the space – conceptually amounting to the acoustic equivalent of a head torch.

Figure 19: "My Modulor" (2016) by Ed Carter, iPhone interface

Figure 20: "My Modulor" (2016) by Ed Carter, wearables

5.2.4 Observations from Practice D: "My Modulor"

The iterative process of creating Practice D: "My Modulor" as a development of Practice C: "SCALE" led to a series of observations, including how personalising scale can by used to articulate and augment the subjective nature of an architectural experience, and the potential of digital tools to playfully create a bridge between quantitative creative methods and qualitative experiences.

5.2.4.1 Personalising scale

Le Corbusier's notion of a universal anthropocentric scale of measurement for architecture and design was fundamentally flawed, in that the user group for whom he was designing was not of those same standardised proportions. Whilst the concept of personalising the built environment in any meaningful way is complex, sound does provide means by which we can tailor subjective architectural experience.

Whilst Practice C: "SCALE" juxtaposed two versions of the "Modulor" proportions to highlight the dissonance between the two sets of measurements in the space, the audience were completely external to this process. An audience member could rightly argue that the project may well raise issues of subjective experience of scale in general, but not of *their* subjective experience of scale.

In Practice D: "My Modulor", by tailoring the scale to each participant, the audience becomes the focus of the work, with their own size and movement dictating the physical and sonic manifestation of the piece, and in turn provokes personalised acoustic responses that are shaped by the architecture.

By focusing the work on the human rather than the building, the piece becomes autonomous and transferable, and therefore arguably more suited as an analytical tool, in the spirit of Lefebvre's "Rhythmanalysis".

5.2.4.2 Digital tools – quantitative to qualitative

Practice D: "My Modulor" is inherently quantitative in its approach, from the measurement system of "Le Modulor", to the scaling software, the numerical user interface, and the digital synthesis of the soundwaves.

However, once a participant begins exploring a space with Practice D: "My Modulor", the outcome is dependent on the interaction between the participant and their surroundings. The quantitative methods are allowed to sit in the background, allowing the participant to engage with their personalised surroundings as a purely aesthetic experience, that is readily understood in qualitative terms. However, due to the freedom the digital tools provided for the participants' to move around the space, their personalised role was neither passive nor involuntary, but an active contribution to the resulting piece, based on their aesthetic decisions.

The process for personalising scale was reliant on digital tools in this project, and the flexibility, mobility, and accessibility this offered was central to the work. However, perhaps a more relevant observation in the context of this research is this manner in which digital tools can enable a qualitative process to be presented as a primarily aesthetic experience.

Returning to the terminology of Louis Kahn, digital tools can be seen as providing mechanisms through which a sense of "unmeasurable qualities" can be invoked, despite having to pass through the "measurable" in the process:

"A great building, in my opinion, must begin with the unmeasurable, must go through measurable means when it is being designed, and in the end must be unmeasurable. The only way you can build, the only way you can get the building into being, is through the measurable… But in the end, when the building becomes part of living, it evokes unmeasurable qualities, and the spirit of its existence takes over." (Lobell and Kahn, 2008: 48)

5.2.4.3 Interior vs Exterior

In contrast to the practical research projects in the "Rhythm" section (Practice A: "Barographic" The Lowry" and Practice B: "Journey"), both Practice C: "SCALE" and Practice D: "My Modulor" intentionally only address architectural context from an interior (rather than exterior) perspective.

The idea of architectural context goes far beyond our relationship with the envelope of a building and its materiality, regardless of whether it is experienced from the inside or outside. There is a reciprocal relationship between a structure and its location. An architect designs for an existing site and social context, but the addition of a new structure fundamentally changes that pre-existing dynamic. This relates to Martin Heidegger's description of the manner in which the addition of a bridge to a stream creates a "locale":

"The locale is not already there before the bridge is. Before the bridge stands, there are of course many spots along the stream that can be occupied by something. One of them proves to be a locale, and does so *because of the bridge*." (Heidegger, 1971: 355-6)

In light of this observation, the third section of this study aims to find connections between the seemingly dialectical perspectives of interior and exterior space, and how liminality can inform sonic composition and interdisciplinary practice.

6 Liminality

6.1 Contextual review:

> "In architecture, only when inside and outside fuse in one integrated vision are we dealing with a work that carries meaning and can be understood as a whole." (Arnheim, 1977: 109)

The previous two areas studied in this research (rhythm and scale) have adopted differing perspectives on the notion of "architectural context" through the associated practical projects, notably with rhythm focusing primarily on an exterior point-of-view, and scale responding to our experience of interior space. This section looks at approaches to tackling what Gaston Bachelard defines as "The Dialectics of Inside and Outside" (Bachelard and Jolas, 1994: 212), considering both architecture and music as "permeable", and how the relationship between the object and its wider context allows "the world to leak into the work" (Alvim, 2018: 58).

For the purposes of this research, the term "liminal" is used in the manner described below:

> "Liminal: Occupying a position at, or on both sides of, a boundary or threshold." (Definition of 'Liminal', 2018)

The concept of liminal space raises interesting questions concerning the nature of architectural boundaries, and the connectivity between the habitable voids created by architectural forms and their external environment. Through further contextual review and my own practice, this section looks at how these concepts are not only relevant to architecture, but also apply to music, sound art, and visual art forms.

6.1.1 Insideness and outsideness

> "But real spatial experience rests on simultaneous
> interpenetration of inside and outside, above and beneath, on the
> communication of the in and the out, on the often invisible
> interplay of forces present and their relationship in space"
> (Moholy-Nagy, 1947: 62)

In creating new work that explores an architectural context, it seems
critical to look beyond the fabric of the building alone, and consider the
manner in which a building engages with its surroundings. As Arnheim
explains, "A building's meaning must be seen in the context of its
setting, as a building is conceived, for the most part, as a stable refuge
amidst the hub of human activity" (Arnheim, 1977: 217).

This sentiment is echoed by Toni-Rose Brookes, who articulates the
role the wider landscape plays in providing a building with its context:

> "When a building is completed it becomes one with the plot of
> land on which it sits. The context of a building, including the
> landscape and setting of which it is placed in, is fundamental to
> the overall perceived outcome and visual expression produced
> by the architectural shapes which are constructed" (Brookes,
> 2012: 29)

Harry Charrington also describes how the architect Alvar Aalto (a friend
of Moholy-Nagy) "deliberately softened the junction between inside and
outside" (Charrington, 2008: 134) by inserting louvres across the
windows in his buildings. This resulted in the "blurring of openings and
solid walls" (Charrington, 2008: 134) and "reconnecting [the space] to
the natural world" (Charrington, 2008: 166) in production of an "Umwelt"
or surround world" (Charrington, 2008: 2).

In "Rhythmanalysis", Lefebvre felt the need to conduct his work from a position that physically bridged the divide between interior and exterior space, asserting that, "it is therefore necessary to situate oneself simultaneously inside and outside. A balcony does the job admirably" (Lefebvre, 2013: 37).

To continue the model of previous practical projects in this research, an approach is required that can respond to a building's relationship with its surroundings, and one that employs both qualitative and quantitative methods. Unsurprisingly, architectural theorists and practitioners have provided numerous perspectives on the nature of this relationship, far beyond the scope of this research. Nevertheless, there are some particularly pertinent contributions which have formed the basis of the approach taken in the practical research projects described below.

Robert Venturi perceived the wall as playing an active role in our perception of the relationship between inside and outside, the envelope of the building functioning as a membrane that separates the two states, or perhaps as an interface that connects them:

> "Since the inside is different from the outside, the wall — the point of change — becomes an architectural event. Architecture occurs at the meeting of interior and exterior forces of use and space" (Venturi, 1977: 86)

Therefore, perhaps it is more useful to think about the point of transition between outside and inside as an interaction, as opposed to a physical point in space. This can be seen as a similar concept to Duncan Patterson's suggestion that "thresholds are not places, they are media" (Patterson, 2011: 5).

However, if, like Philippe Rahm, we reconsider the subject of architecture as being the creation of the void (as opposed to the design

of material structures; Schrimshaw, 2011: 145), the nature of perceived liminal space is fundamentally altered. An opening in the envelope of a building no longer offers a clear distinction between the internal and external void. Instead, space provides a continuous link between the two states, irrespective of the imaginary border that fills the frame of an open window or door. An artistic analogy for this might be the installation of a camera obscura, as used by numerous artists in architectural contexts over many centuries, including more recent works by Olafur Eliasson, Susan Collins, Chris Drury and many more. This device uses a small aperture in the architectural envelope to allow light to flood into a darkened space, naturally projecting an inverted image of the exterior space onto an internal surface.

Gilles Deleuze also suggested that the approach of artists such as Stockhausen and Debuffet had the capability to overcome the inside-outside dialectic (Deleuze, 2006: 158), and one example of sonic artwork that also "frustrat[es] the architectural imperative of an exterior-interior divide" (LaBelle, 2006: 251) is Achim Wollscheid's "Wallfield", in which the artist installed microphones and speakers on both faces of the exterior walls of "Livingroom" by architects Seifert and Stoeckmann, capturing and manipulating external sound to be played back inside the building, and vice versa (LaBelle, 2006: 251). This approach relates to Elizabeth Martin's understanding of how sound highlights the fact that our own bodies engage in constant interplay between internal and external environments, and how this is also true of architecture:

> "In our own bodies physical hearing can be thought of as a dialogue between the inside and outside. In much the same way, architecture also resembles a dialogue connecting outside and inside" (Martin, 1994: 23)

If the ambition here is to overcome the dialectical interpretation of inside and outside, then this seems to be aligned with the initial ambition for

the research to approach both architecture and music not as spatial and temporal art forms respectively, but as art forms that each exist necessarily as both spatial and temporal experience. As Will Schrimshaw describes:

> "In dismantling the boundary established between space and time, the support is removed from [Henri] Bergson's related distinctions — between interior and exterior, matter and mind, and so on." (Schrimshaw, 2011: 211)

However, Venturi's statement raises the question of *how* walls mediate between interior and exterior space, and the extent to which they achieve this under different circumstances. Many commentators have focused on arguably the most literal manifestation of this — the nature of the physical openings present in the envelope of the building. Moholy-Nagy describes how these apertures transform the dynamic between interior and exterior space, allowing the "boundaries to become fluid" (Moholy-Nagy, 1947: 63):

> "Fenestrations produced the inward and outward reflections of the windows. It is no longer possible to keep apart the inside and outside. The mass of the wall, at which all the "outside" previously stopped, is now dissolved and lets the surroundings flow into the building (Moholy-Nagy, 1947: 62)… Openings and boundaries, perforations and moving surfaces, carry the periphery to the center, and push the center outward." (Moholy-Nagy, 1947: 64)

This interpretation is reiterated by both Brookes and Arnheim:

> "Existing within the external boundary, openings act as zones of transition between inside and outside. They allow the admission of the qualities which are characteristic of the "Outside". It is

contact with these qualities that literally puts us in touch with the external environment." (Brookes, 2012: 23)

"Openings mediate between the worlds separated by architectural barriers." (Arnheim, 1977: 226)

However, whilst this gives this piece of research a starting point for interpreting the means by which architecture relates to it's surrounding context, the next steps are to consider how we can perceive this effect both qualitatively and quantitatively.

6.1.2 Openings and openness

"… we find it by no means easy to decide how much of the context we must consider to do justice to a particular building."(Arnheim, 1977: 67)

Returning once again to Louis Kahn's thoughts concerning bridging the measureable and the unmeasurable (Lobell and Kahn, 2008: 48), how can the inside–outside dialectic be addressed in both quantitative and qualitative terms?

The approach taken in this study differentiates between definitions of "openings" and "openness", and proposes that the former relates to tangible and quantifiable apertures in the envelope of an architectural form, whereas the latter describes a less tangible qualitative response to architectural space — a void that spills across boundaries.

Thomas Thiis-Evensen provides a clear example of the quantitative approach, in describing the role of the window:

"[the window] will by its size alone describe the relation of inside to outside. It is invariably the 'struggle' between interior space

and exterior space which the window expresses, a question of whether the interior seems to be drawn outwards or whether it remains protected within the dividing wall" (Thiis-Evensen, 1987: 251)

However, Rudolf Arnheim provides an alternative perspective, suggesting that such a quantitative analysis of *openings* fails to address how we interact spatially and temporally with the resulting architectural form:

> "In purely quantitative terms one can calculate how much of an outside wall is open, how much closed… In order to describe the resulting expression, however, one would have to begin by remembering that the closedness of a wall or mass obstructs our progress through space. Openness makes the surroundings accessible to inhabitants of a building and exposes them to intrusion from the outside." (Arnheim, 1977: 225)

He then goes on to summarise *openness* as the duality of *access* and *obstacle*, each of which require active engagement by the user, in order that Vituri's "architectural event" at the point of transition between outside and inside (Venturi, 1977: 86) can be realised:

> "The openness and closedness of any particular building is experienced as part of this great environmental interplay between access and obstacle… openness explicitly overcomes the dichotomy between outside and inside" (Arnheim, 1977: 226)

Our subjective perception of openness may of course differ in relation to which of our senses are most affected. A large window aperture filled with a clear pane of glass allows light to cross the boundary of the building, providing views in and out of the structure, thereby creating a visual sense of openness. Conversely, covering the same aperture with

louvred panels will impede visual connections between inside and outside, but encourage the movement of air across the boundary, providing a sense of openness through temperature changes brought about by the breeze, and through the sounds and smells which traverse the envelope of the building.

It therefore seems somewhat limiting to allow an ocular-centric viewpoint to dictate the parameters of "openness" unilaterally. Indeed, when discussing the role of glass walls (such as the work of Mies van der Rohe), Patterson describes the prioritisation of the visual senses over physical and acoustic experience as "a dangerous mistake" (Patterson, 2011: 14)

The following practical project ("Dunelm House Project") aims to respond both visually and sonically to its architectural context in terms of the inside-outside relationship, combining quantitative observations of the architecture's physical envelope and its apertures (*openings*), alongside a method for articulating the subjective, qualitative sense of *openness* experienced within a space.

6.1.3 Architectural silence

John Cage's influential work around the concept of silence includes some apposite comparisons between the "silences" in his own musical compositions, and the effects of transparency in architectural and sculptural forms.

Cage spent a period working in László Moholy-Nagy's School of Design (Cage, no date), so it is perhaps unsurprising that Cage's thinking reflects a shared perception of the role transparency plays in the relationship between insideness and outsideness. Both Cage and Moholy-Nagy described glass as providing a building with the means to

"dematerialise" (Joseph, 1997: 88), and saw it as a means of connecting interior and exterior space:

> "In Cage's writing… the reflection on the outside of the building forms a complimentary [sic] pair with the effect of transparency from the inside as a means of visually opening up the building's structure to the environment." (Joseph, 1997: 87-88)

Joseph continues, quoting lectures by Cage from 1952 and 1957, in which Cage expands on his understanding of connections between silence and transparency in music, architecture, and sculpture:

> "For in this new music nothing takes place but sounds: those that are notated and those that are not. Those that are not notated appear in the written music as silences, opening the doors of the music to the sounds that happen to be in the environment. This openness exists in the fields of modern sculpture and architecture. The glass houses of Mies van der Rohe reflect their environment, presenting to the eye images of clouds, trees, or grass, according to the situation. And while looking at the constructions in wire of the sculptor Richard Lippold, it is inevitable that one will see other things, and people too, if they happen to be there at the same time, through the network of wires. There is no such thing as an empty space or an empty time. There is always something to see, something to hear. In fact, try as we may to make silence, we cannot." (Joseph, 1997: 86-87)

One example of this thinking in Cage's practice is his approach to "Variations IV". This site-specific graphic score provides instructions that literally transport sounds from the external environment into the listening space, summarised in Michael Fowler's research on the piece:

> "Cage's work goes… literally outside of the building and back to the landscape, by conceptualising the acoustic space of music as one that is comfortably both an interior (inside) and exterior (outside) experience… the central realisation strategy of *Variations IV* becomes centred on the reconciliation of the aural architecture of the surrounding context (the arena of the unintentional) with that of the architectural interior (the arena of the intentional)." (Fowler, 2012: 160)

One of the interesting results from Cage's approach is the manner in which it manipulates the audience's "acoustic horizon", a term that is defined by Barry Truax as "The farthest distance in every direction from which sounds may be heard" (Truax, no date). Fowler suggests that this approach redefines the parameters that constitute inside and outside:

> "The meaning of "inside" thus becomes defined by the dimensions of the acoustic arena within which the listener is situated, while the meaning of "outside" is represented by the boundaries of the acoustic horizon". (Fowler, 2012: 174)

But perhaps even more significantly, Cage's work highlights the discrepancy between our experience of visual and acoustic horizons, and subsequently raises questions about how these should be addressed when creating new work in response to the perceived *openness* of a specific architectural context to its surroundings. As Moholy-Nagy and Cage suggested, glass may allow a building to "dematerialise" in a visual sense (Joseph, 1997: 88), but acoustically it remains a solid barrier between interior and exterior space, and thereby inhibits phenomenological connections between the two.

This focus on horizons again finds parallels in the work of Le Corbusier regarding "scale". His "new scale" (described in "The Home of Man", published in 1948 – the same year as "Le Modulor") was conceived

around the sense of scale and perspective provided by a visual connection to the horizon, and the assertion that architecture "must account for everything at this new scale: everything to the limit of what is possible to see from any occupiable built form" (Moulis, 2003: 136). The significance of this is that Le Corbusier's horizon provides a subjective scale, the experience of which is open to being "exploited and manipulated" by the architect (Moulis, 2003: 134).

The disparity between how acoustic and visual horizons affect our perception of architectural *openness* is central to the approach I undertook in Practice E: "Dunelm House Project", which looks at the role of liminality in our experience of wider architectural context.

6.2 Liminality: Practical research project

6.2.1 Practice E: "Dunelm House Project"

6.2.1.1 Context

Like Practice D: "My Modulor", Practice E:"Dunelm House Project" was developed as an exploratory piece. The work has only been tested privately to date, without any public presentation, and the observations are made on this basis.

The Dunelm House building opened in 1966 as Durham University's Students Union building on the banks of the River Wear. Adjoining Ove Arup's Grade I listed Kingsgate footbridge (which opened the same year), its windows look directly across the river to a UNESCO World Heritage site incorporating the city's Cathedral and Castle.

Designed by Architects' Co-Partnership, the award-winning brutalist structure was recommended for listed status by Historic England, only to be refused in late 2016 by then Culture Secretary Karen Bradley (Waite and Braidwood, 2017). Since this point, groups such as the

Twentieth Century Society and Save Dunelm House have campaigned to overturn the decision, and protect the building from demolition.

Interestingly for this study, Historic England's report on Dunelm House not only notes the "rhythm" of the uprights between the windows (mullions), it even compares them to those of Le Corbusier's Monastery of La Tourette (Waite and Braidwood, 2017), which were designed by composer and architect Iannis Xenakis (Sterken, 2007: 37).

Figure 21: Dunelm House by Architects Co-Partnership, photo by Ed Carter

Given Dunelm House's stunning surroundings, the rhythmic nature of the apertures in its exposed concrete envelope, and the comparisons made with the work of Le Corbusier and Xenakis, it provides an ideal architectural context for the final practical research project. Furthermore, the current social and political dynamic concerning the building's future provides an additional layer of cultural context for the new work.

6.2.1.2 Process and presentation

The final practical research project responds to Dunelm House within its wider architectural context in Durham (UK), both in terms of its relationship to the surrounding landscape, and its cultural significance (as evidenced by the debate around its precarious unlisted status). The method explores openness and openings as qualitative and quantitative means of engaging with the concept of liminality, when articulating our experience of architectural space.

The project also continues the theme of personalising our experience of architectural context. Duncan Patterson suggests that architect Eileen Gray's window apparatus in her E-1027 villa (operable shutters, louvres, and sliding or folding panes) enabled "a certain degree of controlled subjectivity", whereby they occupant can "make their own relationship with the outside as they wish" (Patterson, 2011: 13). This analysis reflects the approach to liminality taken in this project, which attempts an analog with sound as opposed to light.

Audio captured from the Pure Data patch is available online (https://soundcloud.com/edcarter/dunelm-house-pd-patch-test-no-mic-input).

6.2.1.3 Sonic process

The process began with a site visit to Dunelm House, to measure the windows in the main refectory area, which looks out towards the river, trees, castle and cathedral. The work adopts the perspective of standing in the centre of the refectory looking towards the windows, continuously turning through a 180 degrees sweep (left-right-left, etc.) to take in the entire view through the windows. This approach can be seen as the inverse of the perspective taken by Kammerbauer and Schnellboegl in their "Xenakis Emulator", which interpreted window

rhythms at La Tourette from an exterior point of view, with no connection made to the convent's wider context (Kammerbauer, 1999).

A primary objective for the sonic element of the work was to extend the acoustic horizon (Truax, no date) beyond the sealed windows of the refectory, in an attempt to replicate the visual range from the same location. In order to create this effect, a stereo field recording was taken outside Dunelm House, directionally matching the view from the refectory windows (as a real time sound feed was not a practical option).

To create the sense of looking left to right across the panorama, the recording was then placed into a Pure Data patch (Figure 22), with a constant stereo pan (left-right-left, etc.). In order to reflect the rhythm of the mullions noted by Historic England in their recommendation for listed status (Waite and Braidwood, 2017), the positioning of the window uprights around the room was applied as a timeline to control a mute function, silencing the field recording at each point where the concrete pillars interrupt the visual connection between inside and outside. John Cage's assertion that glass allows architecture to dematerialise (Joseph, 1997: 88) does not apply to acoustic experience (only visual), and this approach aims to reflect this. On one hand this approach mirrors Cage's, with the glass sections allowing the sounds of the outside world in. However, in another respect it inverts his process, in that here, it is the concrete structure that creates *silence.*
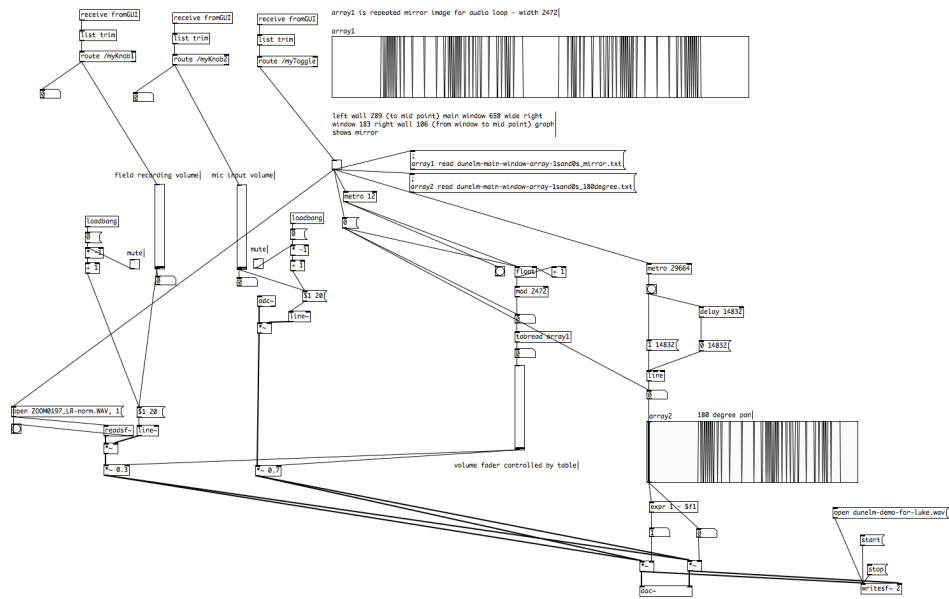
Figure 22: "Dunelm House Project" (2017) by Ed Carter, Pure Data patch

Returning to Eileen Gray's architectural approach allowing people to "make their own relationship with the outside as they wish" (Patterson, 2011: 13), the interface to control the work (built for iPhone, using MobMuPlat) allows the participant to personalise their experience. It does this by offering control over the amount of exterior sound (the outdoor field recording) they wish to hear through the headphones, and providing a second volume control for the inbuilt microphone, to determine how much of their local sounds they choose to hear.
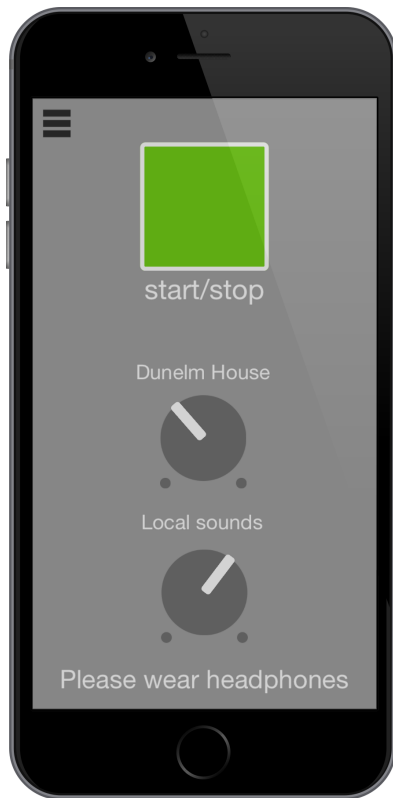
Figure 23: "Dunelm House Project" (2017) by Ed Carter, iPhone interface

6.2.1.4 Wearable process

Whilst responding to the wider architectural context by extending the acoustic horizon beyond the envelope of the building, this project also aimed to reference Dunelm House's social context in some way.

As previously explained, Dunelm House has been rejected for Grade II listed status by the Conservative government in 2016, leading to a campaign to protect the building from redevelopment. Subsequently, the potential demolition of Dunelm House was the catalyst for the wearable/visual aspect of the project, stemming from the notion that, in the near future it may no longer be possible to experience the sense of openness that Dunelm's rhythmic window arrangement applies to its surrounding landscape.

In response to this, laser-cut "glasses" were produced which replicate the spacing of the mullions in the Dunelm House refectory, to be used alongside the sonic version. This element of the project was developed as a playful visual tool, articulating the prospect of viewing the river from the same location in the future, but without the current architectural form to frame the experience.
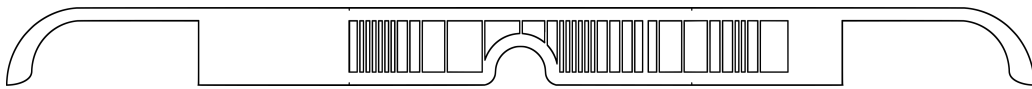
Figure 24: "Dunelm House Project" (2017) by Ed Carter, wearables template

Figure 25: "Dunelm House Project" (2017) by Ed Carter, wearables, photo Ed Carter

6.2.2 Observations from Practice E: "Dunelm House Project"

"The hylomorphic model, Simondon (2005: 46) concludes, corresponds to the perspective of a man who stands outside the works and sees what goes in and what comes out but nothing of what happens in between" (Ingold, 2013: 25).

This project investigated the use of openings and openness as quantitative and qualitative means through which to explore (through creative practice) the role of liminality in shaping our experience of architectural context.

Observations from this working process include the manner in which our nuanced and subjective experience of "openness" is made manifest in architecture by disparities between visual and acoustic horizons, and how digital tools have the potential to personalise our relationship with the "outside" in real time — the thereby shape our relationship with the broader architectural context that lies beyond the fabric of the building. It is also argued that openings and openness can find their equivalents in John Cage's "notated" and "unnotated" sounds, and Louis Kahn's "measurable" and "unmeasurable" architecture — in each instance, it is argued here that the quantitative perspective simply provides a means for framing the qualitative experience.

6.2.2.1 Multiple horizons

> "Is the wall of a glass house just one big window? Or is it perhaps just a transparent wall, without any windows at all… The transgression of the boundary by light and vision has been maximized while physical and acoustical transgression has been relegated to the door and the air-handling system. Apparently the visual has been privileged well above the other senses. This would seem like a dangerous mistake." (Patterson, 2011: 14)

As a practitioner exploring architectural context through liminality, inconsistencies between visual and aural experience provide a tangible method for articulating the subjective nature of openness. Whilst glass is often seen as a way to increase the level of interaction between inside and outside space, it also has the very real potential to increase this disconnect between the senses. For example, a visitor with visual

impairment may be unaware of a 360 degree panoramic window offering a view of the surrounding landscape, but might hear bird song, traffic, or a busy street through the tiny opening of an air vent.

Developing an interdisciplinary response such as this affords the opportunity to manipulate the relationship between visual and acoustic horizons, either to bring them closer together, or to make a more stark contrast between the two. A key observation from the process of creating this work was therefore that reducing the difference between the visual and acoustic horizons has the potential to provide a more consistent sense of "openness", but that this may not accurately reflect the architectural context itself, which may present its openness very inconsistently to our different senses.

As such, different approaches to this may be more or less suited, depending on whether the aim is to respond to an architectural context as a whole (incorporating its wider landscape and social surroundings), or to the real world experience of entering a specific architectural space.

This issue places the same responsibilities on the practitioner as Arnheim noted for architects, with regards to the *amount* of wider context that should be included in the work:

> "… we find it by no means easy to decide how much of the context we must consider to do justice to a particular building." (Arnheim, 1977: 67)

However, taken in the context of Le Corbusier's "The Home of Man", experiencing the horizon provides inhabitants of the built environment with a sense of scale (Moulis, 2003: 136), and perhaps therefore it can be argued that the practitioner must consider liminality of architectural context to the full extent of both its visual and acoustic horizons. Arguably, Le Corbusier's notion of the horizon providing a sense of

scale offers a far more "universal", or at least "transferable", method than "Le Modulor"'s anthropometric approach.

The issue of manipulating the acoustic and visual horizons relates directly to the manner in which digital tools shaped the nature of this project, and to the second observation from the work.

6.2.2.2 Personalising liminality

If openness and openings are accepted as qualitative and quantitative expressions of liminality in architectural form, and visual and acoustic horizons are accepted as two means by which we experience architectural openness and openings, then it stands to reason that the ability to control our visual and acoustic horizons allows us to personalise our experience of architectural liminality.

This concept of tailoring our experience of the relationship between inside and outside space provides a method for engaging with architectural context as a concept that not only extends beyond the fabric of the building, but also as something that is highly subjective.

In this instance, digital and mobile technologies made it possible to accurately translate quantitative details relating to the architectural openings, into temporal events within the piece. They also provided the participant with tools to extend their acoustic horizon in response to their visual sense of openness, thereby controlling the manner in which, and the degree to which, their architectural experience is affected by the wider context beyond the envelope of the building itself.

To achieve a similar outcome with analogue methods would be incredibly challenging, and certainly less compact. Therefore, it is observed once again that digital tools provide flexible and accessible tools for developing and presenting works that provide the opportunity

to personalise our experiences of architectural contexts, and allow us to tailor the aesthetic experience through numerical means.

Further to this, the mobility afforded by the handheld device means the work can be experienced independently of the architectural form itself. By separating the architectural "rhythms" and the sense of "openness" from the building, the work creates a permanent expression of the architectural experience, which can therefore exist beyond the life the physical structure itself. In this sense, the digital tools arguably allow the built form to "dematerialise" to a far greater extent than glass – whose capacity for dematerialising was lauded by both László Moholy-Nagy and John Cage (Joseph, 1997: 88).

The effect of articulating architectural rhythm and openness as potentially transferable and/or mobile serves to highlight the degree to which architectural context is arguably as dependent on its site as it is the fabric of the building itself. This therefore underlines the significance of liminality as a factor to consider when developing work in response to contexts.

6.2.2.3 Measurable openings, and unmeasurable openness

The third observation from this practical research project concerns connections between this approach to exploring liminality through openness and openings, the manner in which John Cage perceived the role of notation in his sonic works, and Louis Kahn's ambition that architecture expressed something that was "unmeasurable".

John Cage described his music as having the same "openness [that] exists in the fields of modern sculpture and architecture" (Joseph, 1997: 86). He achieved this openness by including silences, thereby "opening the doors of the music to the sounds that happen to be in the environment" (Joseph, 1997: 86). Like the fenestrations in a building,

these sonic apertures are quantifiable, they are measurable un-notated sections of the music, framed by the notated sounds which are written into the score. However, the sense of *openness* that the process achieves is a subjective experience, it is unquantifiable and unmeasurable.

Similarly, Louis Kahn acknowledged that his architectural designs were necessarily quantifiable for pragmatic reasons, they needed to be measurable in order that they could be realised. However, his ambition was that the experience they offered was "unmeasurable", the built work simply providing a quantitative frame for the unquantifiable, subjective, phenomenological journeys of those who encounter the space.

Arguably, Kahn's "unmeasurable and measurable", Cage's "un-notated and notated", and this project's "openness and openings" are all better described by the terminology used by Fowler, of "the arena of the unintentional" versus "the arena of the intentional" (Fowler, 2012: 160).

These precedents are helpful in developing interdisciplinary creative work that explores the idea of the architectural context as a liminal concept, whilst incorporating both quantitative and qualitative approaches. In developing this practical project, it was therefore observed that the perceived relationship between openings and openness is subjective, and that quantitative openings merely provide a frame for the complex, subjective, unmeasurable, qualitative sense of openness that liminality can invoke.

7 Findings and Conclusions

7.1 Overview

Returning to the original research questions, this study set out to consider how perceived connections between architecture and music have been interpreted and presented in both experiential and numerical terms, and to explore ways in which these approaches can inform sonic composition and interdisciplinary creative practice, specifically when responding to architectural contexts:

1. How have perceived connections between architecture and music been interpreted and presented in both experiential and numerical terms?

2. In what ways can these approaches be combined to inform sonic composition and interdisciplinary creative practice when responding to architectural contexts?

The questions were addressed through a combination of contextual review and my own creative practice.

In considering the ways in which connections have been made between architecture and music over such a long period of time, one of the central aims was to find approaches that accommodated the idea that both architecture and sound/music each provide experiences that are necessarily both spatial *and* temporal in nature.

With regards to the first question, numerous architects and composers have worked to develop creative methodologies that are intentionally and exclusively either quantitative or qualitative (as described by Sven Sterken, 2007: 31), many of which are covered in the contextual review chapter. However, this research aimed to find practitioners whose work

can be seen to bridge this divide, leading to the citation of examples including the seminal work "I am Sitting in a Room" by Alvin Lucier.

The second research question is addressed through the documentation of the series of practical projects I produced as part of this body of work. Through an evolving, iterative process of contextual review and practice-based research, observations have been provided in response to each of the practical projects. The main findings and conclusions presented here build on these direct observations, but perhaps more importantly, these conclusions aim to present a broader picture of the overarching themes that emerged from the creative process as it evolved in response to those observations.

Through this research process, three main themes were identified, beginning with an interpretation of Henri Lefebvre's work on rhythm, before moving onto scale, and then liminality. The first finding from this research identifies that a methodology constructed around these three areas can provide the basis of a useful framework for a spatial and temporal creative toolset, which has the flexibility to incorporate both qualitative and quantitative interpretations of architectural contexts.

The second finding from this research concerns the relationship between "openings" and "openness" in our perception of architecture and sound/music. It is proposed that a quantitative measure of spatial or temporal "openings" and the qualitative experience of "openness" are synonymous with, and add a new dimension to, Kahn's "measurable and unmeasurable" architecture, Cage's "notated and un-notated" sounds, and Fowler's arenas of the "intentional and the unintentional". In each instance, the quantitative measure merely frames a subjective qualitative experience — which exists beyond the control of the quantifiable form, but is entirely dependent on it in order to exist. These concepts look beyond the geometry of the architectural or musical structure, accepting the interplay between "inside" and "outside" in

understanding an architectural or musical "event" as a part of its wider context.

A related finding proposes that a disconnect between visual and acoustic horizons can provide an inconsistent experience of "openness", which has the potential to affect the aesthetic results across media when creating interdisciplinary work that responds to a specific architectural context. This subsequently implies that our aesthetic experience is open to manipulation through quantitative methods.

The application of digital and mobile technologies in the production of the practical projects leads to a third finding concerning the personalised articulation of our subjective phenomenological experience of architectural contexts. The interactive potential afforded by digital media not only highlights the flaws in Corbusier's attempt to create a universal anthropocentric building scale with "Le Modulor", but it also provides various means by which we can tailor personal experience, the examples here relating to personalised anthropometric scaling (Practice C: "SCALE" and D: "My Modulor") and to participants manipulating their visual and acoustic horizons (Practice E: "Dunelm House Project"). Importantly, the digital process allows participants to personalise their *qualitative* experience of the work, in spite of the technology being inherently *quantitative* in its processing of information. Whilst this doesn't fall within the realms of "interactive art" in the traditional sense, this approach does acknowledge and incorporate the audience member, user, or participant as a vital contributor to the work itself, in much the same way as Jonathan Hill describes architecture as being "made by the user as much as the architect" (Hill, 1998: 6), or how Diogo Alvim perceives music audiences as "co-authors of a shared event" alongside the composer and performers (Alvim, 2018: 59).

The fourth finding proposes that this approach to exploring architectural contexts not only provides a framework for developing context-specific creative practice, but that it can also stand alone as a valuable practice-based research tool for investigating a site or context (as these two terms are fundamentally inter-related). This is supported by observations noting the role its quantitative and qualitative methods played in guiding contextual research, and subsequently uncovering previously hidden details about relevant historical or social issues.

These findings and conclusions are discussed in further detail below.

7.2 Finding 1 — Rhythm, scale and liminality

The approach taken throughout this practice-based research was heavily influenced by Sven Sterken's assertion that the connections between music and architecture have been articulated either through shared "numerical principles", or through "aesthetic effects" (Sterken, 2007: 31). In response to this, the research process set out to explore practice-based research methods that could encompass both of these approaches, thereby incorporating both quantitative (numerical) and qualitative (aesthetic) methods.

Henri Lefebvre's "Rhythmanalysis" provided a useful starting point for this, as an adaptable, transferable approach that can be applied spatially and temporally, in a manner that Lefebvre believed unifies the quantitative and the qualitative:

> **"Rhythm** reunites **quantitative** aspects and elements, which mark time and distinguish moments in it – and **qualitative** aspects and elements, which link them together, found the unities and result from them." (Lefebvre, 2013: 18)

Lefebvre's understanding of "qualitative" experience makes connections between "quantitative" observations, creating subjective associations between measurable events and thereby giving them personal meaning and contextual relevance.

In practice, the approach to "rhythm" that informed Practice A: "Barographic: The Lowry" (section 4.2.1) and Practice B: "Journey" (section 4.2.3) raised aesthetic issues concerning how spatial and temporal observations can be subject to arbitrary scaling during the quantifiable process of translating them numerically across different media. In an attempt to explore this further, the second area of research took inspiration from Lefebvre's interpretation of the body as the measure through which we interpret the world around us:

> "He listens — and first to his body; he learns rhythm from it, in order consequently to appreciate external rhythms. His body serves him as a metronome." (Lefebvre, 2013: 29)

Consequently, and building on Lefebvre's approach to rhythm, the second phase of the research explored an anthropocentric approach to scale and scaling, leading to Practice C: "SCALE" (section 5.2.1) and Practice D: "My Modulor" (section 5.2.3). As the architect Le Corbusier drew so many parallels between his anthropometric "Modulor" scale and the ratios that underpin Western musical scales, highlighting the inherent issues of his attempt to create a "universal" building scale became an initial theme for the practical work. Whilst Le Corbusier's system was unapologetically quantitative in its approach, Peg Rawes proposes that "geometric intuition may give rise to mathematical *and* aesthetic modes of expression" (Rawes, 2008: 5). Furthermore, Rachel Wells suggests that the body is actually better suited as a measure of relative size rather than of relative scale (Wells, 2013: 15), and that in Bergsonian terms, size relates to "quality" (whereas scale is a measure of "quantity") (Wells, 2013: 17). Therefore, it can be argued that the

geometry of our bodies can at least provide a qualitative measure of relative size, even if not relative scale.

In an attempt to bridge this scale/size and quantitative/qualitative divide, each practical research project that addressed this theme (Practice C: SCALE", section 5.2.1, and Practice D: "My Modulor", section 5.2.3) provided participants with another human "form" with which to compare their own body, both visually and sonically (as a means of engaging with their architectural surroundings). In the case of Practice C: "SCALE" (section 5.2.1), the human form was the wooden sculptural form, in Practice D: "My Modulor" (section 5.2.3), it was the other participant.

Another important observation at this stage was the fact that the practical projects so far had only explored architectural contexts from either an exterior *or* interior perspective, and failed to consider the relationship between these two states. In response to this, the third area of research focused on the "dialectics of inside and outside" (Bachelard and Jolas, 1994: 212), and the role of liminality in our perception of architectural contexts.

7.3 Finding 2 — Openings, Openness and Multiple Horizons

In order for this approach to encompass both qualitative and quantitative perspectives, a distinction is proposed between the terms *openings* and *openness*. *Openings* are perceived here as quantifiable apertures between inside and outside environments, measurable either by their physical size or by the degree to which they allow movement across a threshold, in terms of light, sound, smell, airflow, etc. *Openness*, however, is applied here as a qualitative term, describing our subjective perception of a phenomenological experience. If it is accepted that experiences of architecture and sound/music are both

spatial and temporal, then this quantitative and qualitative interpretation of openings and openness is equally applicable to the apertures in the envelope of a building, and to periods of silence in a musical performance – each allows "*the world to leak into the work*" (Alvim, 2018: 58).

In order to articulate this concept through creative practice, this interplay between insideness and outsideness was first represented in Practice E: "Dunelm House Project" (section 6.2.1). This was achieved through exploring our perception of acoustic and visual horizons, again using rhythm (inferred from the fenestrations, or openings, in the building envelope) as a tool for engaging with the architectural context.

This focus on horizons also provided the work with its connection to "scale". Where previous projects (Practice C: "SCALE", section 5.2.1, and Practice D" My Modulor", section 5.2.3) took inspiration from Le Corbusier's anthropometric "Modulor" system, the manner in which Project E: "Dunelm House Project" (section 6.2.1), achieves its sense of scale is more closely aligned with Le Corbusier's "new scale", in which he described the need to "account for everything to the limit of what is possible to see from any occupiable built form" (Moulis, 2003: 136), with the idea that "the horizon provides subjective experiences" (Moulis, 2003: 137).

If this perspective is also accepted in relation to our acoustic horizon — defined by Barry Truax as "The farthest distance in every direction from which sounds may be heard" (Truax, no date) — then providing the means for people to manipulate the relationship between these two sensorial horizons not only enables a personalised, subjective, qualitative experience, but also one that can be manipulated to produce a disconnect or mismatch between the way our different senses perceive their surroundings.

As a specific application of rhythm, scale and liminality as an interdisciplinary creative framework, this interplay between our perception of multiple sensorial horizons therefore evidences a means by which we can separate our aesthetic experience of "openness" from the measurable "openings" that shape and inform it. In many ways this concept represents the culmination of the observations made in response to the iterative practical research process, and therefore forms a central aspect of the proposed contribution to knowledge.

7.4 Finding 3 — Personalisation and digital tools

A number of the practical projects documented in this research serve to highlight the potential for digital and mobile tools to personalise and augment our experience of architectural contexts, and allow participants to tailor creative interdisciplinary work that is developed in response to their surroundings.

This was first observed in response to Practice D: "My Modulor" (section 5.2.3), which built on the process used in Practice C: "SCALE" (section 5.2.1), retaining Le Corbusier's "Modulor" proportions but giving participants the opportunity to tailor the sonic results based on their own physical form. In doing this, the process not only highlighted the inflexibility of fixed scales of production (such as "Le Modulor", or the Western A=440 Hz musical scale), but more importantly, it also provided a tangible manifestation of our subjective experience of the built environment.

Practice E: "Dunelm House Project" (section 6.2.1) continued to pursue this idea of subjective phenomenological experience, this time using digital tools to allow participants to personalise the relationship between their acoustic and visual horizons.

Given that the building at the centre of the piece was under threat of demolition, the digital techniques also allowed the work to be mobile, meaning it could function beyond the limits of architecture itself – either in terms of location, or time. The piece attempted to capture aspects of Dunelm House's relationship with its wider context as a liminal experience, inferring rhythms from the building's openings in order that they could be presented independently of the structure itself in the event of its demolition. The focus therefore moves away from the structure itself, and turns towards the participants' qualitative experience in direct response to a quantitative (geometric) reading of the architect's creative expression. In this sense, the building is effectively removed from the relationship between the architect and the user, replaced by an audio-visual interpretation of the sense of "openness" created by the space. In this sense, the digital tools can be seen as allowing the built form to truly "dematerialise", which was the term used by both László Moholy-Nagy and John Cage to describe the effect of glass in architecture (Joseph, 1997: 88).

However, returning to the aim for this research to consider both quantitative and qualitative approaches to interpreting phenomenological experience of architectural contexts, an interesting observation from these practical projects is the manner in which these inherently quantitative digital techniques provided the means to personalise the participants' subjective, qualitative experience. Given the fundamental numerical processes that underpin digital technologies and their associated programming, it could be argued that any digital methodology that invokes an aesthetic response essentially bridges the quantitative and qualitative at some stage in the process. As such, whilst one may not agree with Xenakis that *all* things are "furnished with numbers" (Xenakis and Kanach, 1992: 202), digital processes inevitably are. So it perhaps isn't accurate to say "We are all Pythagoreans" (Xenakis and Kanach, 1992: 202), but it might be more reasonable to suggest that "*Digital practitioners are all Pythagoreans*".

7.5 Finding 4 — Practice-based research tool

Alongside providing a framework for creating new interdisciplinary work in response to architectural contexts, the fourth finding describes how this combination of rhythm, scale and liminality can also be employed as a stand-alone, transferable practice-based research tool for gaining greater social and historical insight into a specific site or context. In this application, it is therefore proposed that the framework is not restricted to being a tool solely for creative practice, but that it can also be employed more widely in research that exists outside of the arts.

The basis of the approach can be seen as an adaptation of Lefebvre's "Rhythmanalysis", which Stuart Elden describes as "a *tool* of analysis rather than just an *object* of it " (Elden, 2013: 5). However, whilst rhythm itself plays a key part in each of the practical projects documented in this research, it is proposed that the additional specific attention to the subjective nature of both scale and openness (the latter as an articulation of liminality) offers a new perspective to exploring spatial and temporal aspects of our surroundings through both qualitative (aesthetic) and quantitative (numeric) means.

In practice, the results of employing this approach are perhaps most evident in the projects documented in the chapter on Rhythm — Practice A: "Barographic: The Lowry" (section 4.2.1) and Practice B: "Journey" (section 4.2.3). In each case, observations made during the process of interpreting and translating the geometry of the architecture across media guided the research process, and subsequently uncovered additional information about the social history of its architectural context.

In the case of Practice B: "Journey" (section 4.2.3), a simple exploration of Singapore Art Museum's current façade using golden ratio rectangles led to unexpected associations being made between the architectural

proportions and the ecclesiastical history of the building and its architects (section 4.2.4.2).

The process suggested possible repeated cross shapes, formed by golden ratio rectangles in the building's front elevation. This observation led to further research about the architects behind the work, who were part of the Catholic church and significantly, designing a religious school. Whilst it seems plausible under the circumstances, it is not claimed here with any certainty that the architects intentionally used crosses in their design. However, it is claimed that this creative process informed the direction of the research, with the geometry of the architecture being employed as a graphic score, and observations from that score consequentially guiding historical research into the architectural context.

As George Hersey states "the shapes an architect chooses are matters of fact; how he arrived at them is a matter of opinion" (Hersey, 2000: 14), so to speculate about any architectural intent behind the observed crosses at Singapore Art Museum is mere conjecture. However, Hersey does also acknowledge the capacity for this type of observation to reveal hidden architectural connections, stating that, "the analysis of geometrically constructed plans and elevations can reveal connections between architectures that, from a strictly stylistic viewpoint, seem unrelated" (Hersey, 2000: 223).

Subsequently, this practice-led research process is proposed as a method with the capacity to highlight potential hidden connections that may not be immediately obvious in the built architectural form. It does not claim to confirm these observations as fact, but that the process provides an additional means by which to explore an architectural context, and to guide and inform the wider creative research process.

7.6 Summary and contribution to knowledge

The four findings defined above constitute the proposed contribution to new knowledge derived from this piece of practice-based research. Alongside these practical findings (and the creative work itself), it is also claimed that the combination of interdisciplinary theorists and practitioners that have influenced the research process represent a new contribution to existing contextual interpretation of the field.

From the perspective of a practitioner developing work in response to architectural contexts, this iterative process of practice-led research worked towards establishing an interdisciplinary creative approach with the intention of bridging aesthetic and numeric, and spatial and temporal, interpretations of the built environment. The aim is that the findings and creative framework outlined herein will be of value to other practitioners, and that by placing this research within an interdisciplinary historical context, it may help to inform future practice-based research in this area.

Furthermore, by bringing a range of alternative perspectives to the relationships between architecture, sound, music, and interdisciplinary practice, this research aims to provide new ideas that can help to overcome the aesthetic and numerical dialectic that is associated with this area. With interesting contributions from Rachel Wells on scale versus size, Peg Rawes' interpretation of Kantian geometry, and Henri Lefebvre's use of rhythm to bridge the qualitative and quantitative, this thesis aims to offer some valuable new material on the issues of what Schelling described as "the imagination of the infinite into the finite, of the ideal into the real" (Schelling, 1859: 629).

To summarise, influenced by Louis Kahn's ambition to create architecture that navigates between the measurable and the unmeasurable, and John Cage's use of notated and un-notated sounds,

it is proposed that interpretations of rhythm, scale, and liminality can provide transferable and flexible techniques through which the practitioner can explore the spatial and temporal nature of architectural contexts, using both qualitative and quantitative means.

Like the spatial and temporal elements of the two disciplines (architecture and music), the quantitative and qualitative are inextricably linked. The quantitative merely frames the qualitative. Kahn's "measurable" architectural forms frame the inhabitants' "unmeasurable" experience; John Cage's "notated" sounds frame the audience's experience of the "un-notated" sections in his music; and similarly, if the inside-outside dialectic is interpreted through its "measurable" visual and sonic openings, these simply frame the "unmeasurable" sense of openness that they create. In essence, the object(ive) frames the subject(ive).

Finally, with reference to the work of Barry Truax and Le Corbusier, the research attempts to realign our phenomenological relationship with architectural space towards a focus on how we relate to multiple, independent sensorial horizons (in this case, acoustic and visual). As a consequence of this, the debate concerning the relationship between architecture, sound/music, and interdisciplinary art, becomes a question of how we experience openings and openness, not how we examine enclosures.

7.7 Reflections and future research

As described earlier, the process undertaken for this research followed an evolving, iterative approach, the results of which are documented in this thesis.

However, alongside the research-specific works produced as part of this process, I also continued my wider creative practice through a

series of other projects. Some of these works incorporated aspects of the themes, concepts, or creative techniques explored in the main body of this work, but tended not to offer any additional insight to the research aims.

For example, I wrote and produced the score for another projection-mapped piece by NOVAK, this time onto the BAFTA headquarters in central London, titled "195 Piccadilly" (2016). For this piece, the opening musical section incorporated rhythms that were written to reflect the proportions in the architectural façade, in a similar manner to Practice A: "Barographic: The Lowry", and Practice B: "Journey". As there were no new observations made in response to this project, it has not been featured in detail within this thesis. Nevertheless, documentation of the event is available online (http://edcarter.net/home/bafta-195-piccadilly/), and the process has been covered in various talks and presentations, some of which are also available to view online (e.g. https://youtu.be/4XqmAukQp1k).

However, another of these projects, "Bridges" (2018), provided some useful context which served to highlight an important limitation of the core practical projects, and thereby offered a potential area for future research within the field. Each of the practical research projects documented in this thesis was developed in response to large, public architectural contexts – specifically a theatre, art galleries, and a students union. Each of these spaces is designed to provide a cultural function, which thereby shapes the relationship we have with them. To paraphrase Martin Heidegger, we inhabit them, but we do not dwell in them (Heidegger, 1971: 1).

"Bridges", as the name suggests, responded to a different type of architecture — although still not a dwelling. In the context of this research, it raised questions about how approaches to rhythm, scale, and liminality may vary in different types of architecture, and

demonstrated how transferable these three themes are as a creative toolset.

The process behind "Bridges" once again clearly expresses Lefebvre's definition of **rhythm** being present wherever there is a place (each bridge), a time (the duration of the light passing over each bridge), and energy expended (the movement of the light across the bridge). It also engages with issues of both relative **scale** (through comparative sonic interpretations of the different bridges) and relative size (through the fisherman's interactions with each bridge, as he passes beneath them). But perhaps most interesting is the manner in which "Bridges" highlights questions about **liminality** through the relationship it playfully depicts between quantifiable architectural openings and the qualitative sense of openness they provide for the fisherman character (or choose not to provide, in some cases). Furthermore, the aperture (opening) provided for river traffic beneath the Tyne Bridge is (for pragmatic reasons) very different to that provided for road traffic crossing the bridge, but "Bridges" only observes the sense of openness it provides from one perspective (following the boat's direction of travel along the river), and does not engage with the opening or openness experienced by the perpendicular flow of road traffic travelling across the river. This highlights the fact there is never a single, universal phenomenological experience that can comprehensively define an architectural context.

Whilst the focus of this research to date has benefitted from the chosen architectural contexts providing a degree of consistency, "Bridges" highlights that there is ample scope for the findings of this work to be applied to different architectural contexts in future practice-based research. It is understandable that the degree of openness an architect provides when designing a raised walkway might be dependent on very different parameters to the process of creating a living space, a bothy, or a bird hide, but it is also important to consider how openings and openness are experienced through personal interactions and

perspective. One potential area for future research would be to explore outcomes from the rhythm/scale/liminality process when applied to architectural contexts which constitute "dwellings". This might be expected to present different outcomes, particularly in terms of the sense of openness the architecture invokes.

Further details about "Bridges" are provided in Appendix IV: "Bridges", and information about the project is available online (http://edcarter.net/home/bridges/), including a short documentary about the creative process (https://vimeo.com/281964263).

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9 Appendices

9.1 Appendix I: Practical project list and credits

Practice A: " Barographic: The Lowry"

Video and sound installation, and live composition by Ed Carter.

Musicians:

Ed Carter – electronics

Jill Fogden – piano

Lucy Hoile – cello

Peter Mitchell – vibraphone

Claire Roberts – violin

Rory Storm – viola

Ellis Thompson – violin

Commissioned by The Lowry.

Practice B: "Journey"

Video-mapped projection by NOVAK.

Music written and produced by Ed Carter.

3D printed graphic score by Ed Carter.

Commissioned by Night Fest Singapore.

Practice C: "SCALE"

Sound and sculptural installation by Ed Carter.

Commissioned by Sculpture 30.

Practice D: "My Modulor"

Mobile sound and wearable artwork by Ed Carter

Practice E: "Dunelm House project"

Mobile sound and wearable artwork by Ed Carter

"BAFTA 195 Piccadilly"

Video-mapped projection by NOVAK.

Music written and produced by Ed Carter.

Musicians:

Ed Cross – violin

Ele Leckie – cello

Chrissie Slater – viola

Commissioned by Lumiere London.

"Bridges"

Written and directed by Ed Carter

Music composed and produced by Ed Carter

Co-written by Katie Simmons

Design and animation by NOVAK

3D character rigging by Murray Lambert

Music performed by Royal Northern Sinfonia

Conductor and orchestration advisor – Timothy Burke

Recording and mix engineer – Richard Halling

Commissioned by Sage Gateshead as part of the Great Exhibition of the North. Supported by Sunderland University and Arts & Humanities Research Council.

9.2 Appendix II: Practical project online documentation

Practice A: "Barographic: The Lowry"
http://edcarter.net/home/barographic-the-lowry/

Installation video: https://vimeo.com/339952876

Performance video: https://vimeo.com/340200593

Practice B: "Journey"
http://edcarter.net/home/journey/

Presentation video (with NOVAK visuals): https://vimeo.com/81089715

Practice C: "SCALE"
Installation video: https://vimeo.com/340193968

Practice E: "Dunelm House Project"
Pure Data patch test audio:
https://soundcloud.com/edcarter/dunelm-house-pd-patch-test-no-mic-input

BAFTA 195 Piccadilly
http://edcarter.net/home/bafta-195-piccadilly/

Presentation video (with NOVAK visuals): https://vimeo.com/153124818

Audio:
https://soundcloud.com/edcarter/bafta-195-piccadilly-soundtrack

Bridges
http://edcarter.net/home/bridges/

Making of video: https://vimeo.com/281964263

Trailer video: https://vimeo.com/281273173

Trailer audio: https://soundcloud.com/edcarter/bridges-soundtrack-promo-edit

9.3 Appendix III: Selected dissemination / public outcomes

9.3.1 Talks, presentations, and panels

"Metre to metre: Architecture and Composition"
Invited talk at TEDx Manchester (February 2016)
https://youtu.be/Q2qwySdUo28

"Tangible Data"
Invited panel member at Convergence London (March 2016)
With Stefanie Posavec (artist), Prof Bill Gaver (Goldsmiths) and Dr Mitra Memarzia (Seeper)
http://www.convergence-london.com/sessions/seeper-presents-tangible-data

Future Everything
Interview/Q&A at Future Everything (March 2016)
http://futureeverything.org/events/fireside-chat-ed-carter-david-cranmer/

"Singapore Art Museum: architectural composition"
Invited talk at the National Museum of Singapore (August 2016)
http://novakcollective.com/work/journey-projection-mapping/

"Global Resonances - Singapore Art Museum"
Talk at BALTIC, Gateshead for the Northern Bridge Autumn Conference (October 2016)

Culture and Knowledge Exchange event
Invited talk at Culture Lab, Newcastle University for Creative Fuse North East (June 2017)

"Architecture and music as spatial and temporal geometries"
Talk at BALTIC, Gateshead for AHRC student conference (July 2017)

"Rhythm and Context"
Invited talk at BALTIC for SP-AN event, programmed by Google Design / It's Nice That (Oct 2017)
https://youtu.be/4XqmAukQp1k

"Place + Time + Energy Expended"
Guest lecture at Northumbria University (November 2017)

"Context – rhythms and stratigraphies"
Guest tutor at Durham University (November 2017)

"Public Making"
Guest lecture at Culture Lab, Newcastle University (April 2018 and March 2019)

9.3.2 Selected installations, exhibitions and performances

"Barographic: The Lowry"
Installation and live performance at The Lowry, Salford (November 2015 - February 2016)
http://www.thelowry.com/event/right-here-right-now

"SCALE"
Installation, and meet the artist, Sculpture 30 festival, Gateshead (March 2016)
https://bit.ly/2wJxlGm

"195 Piccadilly"
Installation at BAFTA headquarters with NOVAK for Lumiere London (January 2016)
http://edcarter.net/home/bafta-195-piccadilly/

"Journey"
Installation at Singapore Night Festival with NOVAK (August 2016)
http://edcarter.net/home/journey/

"Bridges"
Animated film with full orchestral score, multiple daily screenings at Sage Gateshead as part of Great Exhibition of the North (June - August 2018)
http://edcarter.net/home/bridges/

9.3.3 Media

BBC Radio 6 Music
Interview on the Mary Anne Hobbs show (December 2015)
http://www.bbc.co.uk/programmes/p03d49b2

BAFTA podcast
Interview about "195 Piccadilly" with NOVAK (January 2016)
http://www.bafta.org/heritage/photography/lumiere-london-exhibition

Look North TV news
Feature and interview about "Bridges" at Sage Gateshead, as part of Great Exhibition of the North (August 2018)

It's Nice That website
Review of talk at BALTIC, Gateshead, programmed by Google Design /
It's Nice That (October 2017)
https://www.itsnicethat.com/features/newcastle-gateshead-googlespan-event-241017

BBC Boring Talks Podcast
BBC podcast about the musical potential of the roof at Markham Moor
Service station (February 2019)
https://www.bbc.co.uk/programmes/p070hpmy

9.4 Appendix IV: "Bridges"

9.4.1 Overview

"Bridges" was commissioned by Sage Gateshead, for presentation as part of the 2018 festival Great Exhibition of the North. For this project I interpreted seven bridges that span the River Tyne between Newcastle and Gateshead as graphic scores, and used this approach as the basis for an animated film and synchronised orchestral score. Other contributors to the project included Royal Northern Sinfonia (RNS) who performed the soundtrack, award-winning children's TV script-writer and producer Katie Simmons as co-writer, designers and animators NOVAK, and conductor Timothy Burke.

The 25 minute short film was presented to around 10,000 people over the course of Summer 2018, with a focus on young people, school groups, and families. The live premiere was also at Sage Gateshead, with the score once again performed by Royal Northern Sinfonia with conductor Timothy Burke, on 20 May 2019.

The narrative follows a small boat along the River Tyne, and a light on top of the boat acts as a visual "playhead", which traces the architectural "rhythms" in each of the bridges.

9.4.2 Engagement programme

As part of its education work, the host organisation (Sage Gateshead) developed an associated engagement programme for school groups to undertake after watching the film.

This programme provided an opportunity to gather some audience feedback, resulting in two days of data collection (17-18 July 2018)

where teachers completed questionnaires regarding the experience, and their group's understanding of the process.

For the data collection days, the teacher script was altered to focus specifically on "Bridges" and the process behind the project. After watching the film, classes were given a brief explanation of traditional music notation and graphic scores, and how the "Bridges" score responded the bridges across the River Tyne. Classes were then played three short music excerpts: the melodies from the Millennium, Tyne, and Queen Elizabeth II bridges from the film. For each looped melody, the children were invited to create a graphic score in response to the music.

It is important to note that teachers gave different levels of guidance to their groups (which varied a great deal in age from 5 to 15), which undoubtedly had an impact on how the children's drawings and understanding evolved.

The full survey results are included below showing the degree to which the teachers felt their classes had understood or engaged with the process, and photographs were also taken of all the graphic scores produced by the participants (available on request).

However, for the aims of this research, some of the more insightful outcomes came from children's direct quotes captured during the sessions.

Perhaps unsurprisingly, there were clear links made between the terms "high" and "low", and their relationship to both architectural elevation and sonic pitch:

> "When it went high, up the bridge, the music went higher and when it went low the music went lower".

When asked more involved questions about the musical rhythms reflecting perceived rhythms in architecture, one Year 5 group provided a useful explanation of their understanding of the relationship:

> "There are patterns and structure in architecture and there is in music too".

Perhaps even more relevant was that they suggested that this could also inform their interpretation of other art forms:

> "Yes, and also when we look at sculptures".

In terms of connecting all the themes between architecture and music as temporal and spatial experiences, perhaps the most pertinent response came from a child who ran out of space in the box provided for their drawing. When asked what had happened, they simply said it was because the looped song "went on too long" – i.e. they didn't have enough *space* in which to draw that amount of *time*.

9.4.3 Questionnaire results

The questionnaire used anonymous participant codes to retain the anonymity of the participants. These are shown in the left-hand column.

Q1. What year group did you take to see Bridges?

XBDY	Year 3
EU81	Year 4
KTR1	Year 5
CXZ3	Year 3
JQS5	Year 2
7XF8	Year 6
KXNR	Year 10
V9AR	Year 1
DPPK	Year 2
CJT7	Year 2

Q2. In Bridges, the melody for each bridge relates to the shape of the bridge itself. Was this explained before the screening?

XBDY	N/A - we missed the beginning
EU81	No
KTR1	No
CXZ3	No
JQS5	No
7XF8	No
KXNR	No
V9AR	No
DPPK	No
CJT7	No

Q3. Whilst watching Bridges, was the connection between the music and the shape of the each bridge apparent to you / the group?

XBDY	Yes
EU81	In some respects
KTR1	Yes
CXZ3	Yes
JQS5	No [NB: see next response]
7XF8	By the end, yes
KXNR	Yes but not all students
V9AR	Yes
DPPK	Not the shape, but they recognised the link between the bridges closing and opening.
CJT7	No [NB: see next response]

Q4. How would you describe the relationship between the boat's light, the shape of each bridge, and the music?

XBDY	Violin when it was signing [sic - shining?] on the bridge
EU81	The boat seemed like a welcome stranger who communicated with each bridge as it passed through
KTR1	The light scanning the bridge seemed to echo the sound of hands / fingers on strings. The sound had a 'swooping' effect which matched the movement of the light/bridge.
CXZ3	When the bridges went down the music was louder and shorter. The boats light was seeking permission showing it was friendly.
JQS5	Clear link to light and patterns in the music. The music had more of a relationship to the way the bridges moved than their shape for me personally.
7XF8	They seemed to be connected. The light followed the shape of each bridge and seemed like the 'key' to each bridge. The music helped to build the tension/drama of being trapped by the bridge.
KXNR	The music varied depending on the light and when it highlighted a

	bridge
V9AR	The light and shape and dangers of each bridge were told through the music
DPPK	[No response]
CJT7	The light followed the outline of each bridge. In times of peril, the light became a beacon of hope for the fisherman.

Q5. Do you think your school group were aware of a connection between the boat's light, the shape of each bridge, and the music? If so, in what way?

XBDY	They were a bit young to see the connection
EU81	Yes, because of the synchronisation between the light, bridge and timing of the music
KTR1	[Quotes from children]: "As it goes along - it's a bit like a harp - it was going in the shape of the bridge" "It matched up really well; the animation with the music" "When it went high, up the bridge, the music went higher and when it went low the music went lower"
CXZ3	Yes, one child was conducting during the performance. Also as the music changed they shifted in their seats. EAL (English as an additional language) children really enjoyed the experience as language was not a barrier.
JQS5	Some children were probably aware of the connection between the boat's light and the music. I think they are quite young to be aware of some of the connections. They very much enjoyed watching the film and loved spotting familiar landmarks.
7XF8	I think this would vary depending on each child. Some (only a few though) noticed the light & bridge connection. However, I think most children were too involved in trying to unpick the story as opposed to connecting the music, light and bridge shape.
KXNR	Yes - Students seemed to identify changes in the music / sound

	depending on the scene - Noticed during faster music more representation of waves etc
V9AR	Children were able to pick up on the emotion associated with the music, some children were scared, excited, relaxed at different parts depending on the music
DPPK	I don't think they did
CJT7	Responses from children: - Different music for different bridges - Some of the colours in the music matched the colours of the film - Some of the music was scary & matched what was happening - Dark music & blue/light/happy - Colours represented the music Sea > orange > danger/warning current

Q6. When drawing their "graphic scores" inspired by the bridge melodies, in what ways did the group connect visual and musical ideas? Do you feel this was influenced by the connections made in the film between the bridges and their melodies?

XBDY	They knew which music was dramatic and which was soft. However, again I feel they were too young for the activity
EU81	There was a connection with squares, circles and water. In particular, one pupil said track 2 [Tyne Bridge melody] reminded him of the film Titanic.
KTR1	[Quotes from children]: The way I was drawing the shapes was almost in the shape of the bridges - especially the shapes"" (task 2) "Mine went more jagged and pointy when the music was loud" "I was thinking of water, especially the first and third bits of music" "The light and the music were connected"
CXZ3	You could see the children really connecting with the music. They appeared "in the zone" for want of a better phrase.
JQS5	Many children drew bridge like shapes. I do think the film influenced

	this.
7XF8	Most children attempted to draw scores which reflected the music.
KXNR	A lot of students created lines based on the various emotions they felt.
V9AR	I think the children were able to use colour to convey mood, yes I believe it was influenced by the music
DPPK	In some pieces you could clearly see links in the shapes they drew and the higher/lower pitches. We had done a similar activity as school with Rob Kitchen who works at Sage Gateshead.
CJT7	The children have recognised the music from the film & drawn their own representation of this. They have made the link between the 2

Q7. The Bridges music was based on the idea of "rhythms" in architecture. Is this something you or your group had considered prior to watching the film?

XBDY	No I wasn't aware
EU81	No
KTR1	[Quotes from children]: "There are patterns and structure in architecture and there is in music too" "The film wouldn't be the same without the music" "I would need the film to understand the rhythm of the music"
CXZ3	We had not but the children certainly made the connection
JQS5	No
7XF8	No - sorry!
KXNR	No, we were unaware of the film content
V9AR	We use rhythms and patterns a lot in music but would enjoy connecting it with painting in the class
DPPK	No
CJT7	No

Q8. Having watched Bridges, do you think "rhythm" is something you or your group may consider in future when looking at architecture?

XBDY	Yes definitely
EU81	Yes, repeated patterns and height differences
KTR1	[Quotes from children]: "Yes, and also when we look at sculptures" (group went to Baltic after the Sage) "The film made me understand what the artist felt when he was looking at the bridges"
CXZ3	Definitely. I'm sure the children will be keen to share their experience with others.
JQS5	With older children it would be easier to do work based on this.
7XF8	It's difficult to say as the group have a very limited knowledge of architecture so if they were to study it, they would need to start with more basic concepts.
KXNR	We found it very interesting and staff and students were engaged. I think this is something we would consider going forward.
V9AR	Yes
DPPK	Yes - its an interesting idea I think they could
CJT7	The children are a little young to make such a complex connection but we are hoping to use it as a stimulus to explore the bridges further & their importance to Newcastle. We may add music & rhythm to images in future.

Q9. Please feel free to use this space to leave any other comments or feedback

XBDY	[No comments]
EU81	Sound lends itself well to representations found in art work
KTR1	[Quotes from children]: "It was really good" "The music told the story like Peter and the Wolf" "If I was told it was about the bridges the music could help me visualise the story" "It has really inspired me the get involved in animation"
CXZ3	We thoroughly enjoyed both the film Bridges and drawing what the music looked like to us. It was especially great to meet Ed. Thanks for a great experience.
JQS5	[No comments]

7XF8	An interesting film to watch, which I think would have more impact after a second viewing.
KXNR	[No comments]
V9AR	Children were able to connect and enjoyed sharing ideas. The animation was visually appealing to the children and children understood the story. Thank you
DPPK	[No comments]
CJT7	[No comments]