Homogeneity and Heterogeneity

Two Approaches for Designing Spatial Sound

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MASTER OF DESIGN

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Declaration

I certify that except where due acknowledgement has been made, the work is that of the author alone; the work has not been submitted previously, in whole or in part, to qualify for any other academic award; the content of the exegesis is the result of work which has been carried out since the official commencement date of the approved research program; any editorial work, paid or unpaid, carried out by a third party is acknowledged; and, ethics procedures and guidelines have been followed.

Signed

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We all view the world through the ‘window’ of our senses.

– James Cornman

The designer designs not only with the mind but with the body and senses

– Donald Schön

To understand what a thing is, is to work out the space suggested by the dimensions of that thing

– François Bayle
Introduction

My research explores the process for designing and reproducing spatial sound through two personal sound-design projects: *Pilate* (2006) and *Metamorphosis42* (2009). Located within the context of design, it explores two modes for spatial sound composition, which at its heart contemplates the potential for the phenomenon of the sound experience to guide the design and reproduction of spatial sound using electroacoustic techniques. The intent is to convey an approach to sound design, by combining the concepts with the tools and techniques used in sound composition, to create an impression of space that is perceived by the listener. This process has enabled me to draw a distinction in approach between my projects, based on the concepts, tools and techniques I apply in the act of making, to guide my work. In emphasising the sound space relation, the notions of the ‘homogeneous’ and the ‘heterogeneous’ emerge. I apply these terms in my research, to embody the essence of a compositional methodology, explored through an analysis of my projects and by engaging with a process of reflection and listening.

On this basis, my research suggests that the notion of the ‘homogeneous’ builds on the physical relations of sound and space through an experience of sound within space. If our experience of sound in a real-world scenario can be considered coherent, then, in the context of a sound design process, my research proposes that a ‘homogeneous’ approach to sound composition seeks to faithfully reproduce the perceptually coherent sounding qualities observed in the real-world. This approach is predicated on the fact that the sensations of sound are the result of vibrating materials. The displacement, which occurs at the material surface, creates a pressure wave that moves through the atmosphere interacting with other materials within the environment. As a consequence, the pressure waves that reach our ears come from all directions, not just one and the physical qualities of the materials the pressure wave interacts with – their size, shape and density, for example, directly influence how sound is perceived.
The notion of the ‘heterogeneous’ builds on the internal relation of sound and space - the space within sound, and how the physical and imagined qualities of space are interchangeable which conveys a dynamic and complex sense of space. A quality of this approach is that sound is suspended in its own time and space through a poetic re-imagination - an interior space in which sound is decoupled from its physical source. As François Bayle (2007, p.241) writes, ‘a sound from a transducer is like no other’. I interpret this as a way to think about the reproduced sound, which sits beyond the physical. I use the term ‘re-imagination’ to emphasise that the listener is not passive, but instead an active body engaged in this contemplation of sound. On this basis, the heterogeneous is not one singular homogeneous image bound entirely by the physical nature of the source. Instead, it is an affective experience that is bound to our senses and our emotions, reaching our ears through a patchwork of sounds that collide in space and time creating a transformation that occurs at the boundaries of perception.

These two modes of working with sound intrigue me, in as much as I am intrigued by the shift in my practice since beginning my research. My research utilises a reflective approach for the study of my projects, to better understand the aesthetic choices made whilst creating each project, rather than a single proposition used for guiding my work. This approach to my research presented a degree of freedom, allowing me to choose two projects that were separated in time by almost three years. This enabled me to build the theoretical framework that supports my research, but it also provided the time for me to reflect on my practice and the processes and techniques I use to design. On this basis, my research questions are:

**Question 1.** How can the notions of the homogeneous and heterogeneous be used to frame the process for designing spatial sound?

**Question 2.** What compositional techniques can be used to emphasise homogeneous and heterogeneous qualities?
Mapping the domain

Design, phenomenology, the built environment and spatial music are the practices and discourses that inform my research. My research is located within the heart of my sound design practice, which I see situated between the physical space of the built environment and the imagined space of spatial music, as shown below in Figure 1. The importance of the sound and space relation in my research, is that it suggests a process in sound design, which utilizes electroacoustic tools and techniques to convey a spatial listening aesthetic.

Figure 1: The practice of sound design: situated between the physical and imagined.

From the image above, emerging from the practice of sound design are the two modes of spatial sound composition, which I describe in my research as ‘homogeneous’ and ‘heterogeneous’. Bridging the space of the physical and imagined is the practice of phenomenology, which at its core is an understanding of the world through the lens of the senses. This connection is symbolic of the conceptual pathway I use to differentiate between the two modes of sound composition by contemplating the relation between the experience...
of sound and the context in which sounds are perceived. I use the notion of the imagined space to emphasise the affective experience of sound – reaching beyond the physicality of the object and connecting with the hidden interior. The intersection with spatial music extends the notion of the hidden interior to a process of working with sound within a musical context. By linking the built environment to the physical space, I am emphasising the performance spaces in which my projects have been presented, but also contemplating acoustic space – the experience of sound within space and the effect the physical environment has for shaping the sounds we hear.

Even though my research is not grounded in the study of phenomenology or acoustics, they each offer a view of the world that complement the concepts and ideas introduced in my research. Phenomenology focuses on the phenomena we experience within the world through the lens of the subjective experience. In terms of the sound phenomena, it offers my research a deeper level of understanding of the knowledge that can be attained through sense perception – an active and lived engagement with the things we sense within the world. Acoustic theory emphasises the physical relations between sound and space and the knowledge gained from an understanding of the sound phenomena through physical interactions with the environment. In the context of sound design, the associated physical and aesthetic values of sound play a key role in communicating the perceptual characteristics of the sounds we hear, just as the context in which a sound is heard, plays an important role in communicating the features of the environment that surrounds the listener. Applying this knowledge to my own work has enabled me to better understand how the notions of the ‘homogeneous’ and ‘heterogeneous’ can be used to frame a compositional approach. Once unpacked, these terms can be used to guide creative activities, to modify and organize the perceptual characteristics of sound, to convey an impression of space that is experienced by the listener.
Design: setting the scene

The designer constructs the design world within which he/she sets the dimensions of his/her problem space, and invents the moves by which he/she attempts to find solutions.

– Donald Schön

When working as a freelance sound designer for theatre, prior to starting my research, my role was to tell a story using sound supporting a narrative that was central to the dramatic experience. During this time I considered the act of designing to be a natural extension of my practice. An organic, free-flowing process that was embedded and intertwined with so many other things I just did. The significance of Schöns’ views on the practice of design, is that it brings to the foreground the designers thoughts and actions for solving design problems by engaging with the process of making through sensory awareness. This sensitivity to the practice of design enables the designer to better understand their materials, but also find creative ways in which to apply them in problem situations. But the process of finding solutions to problems is not as simple as it might sound. As Schön suggests, it is unlocked through an interaction with the materials and a sense-awareness of ones actions through a process of reflection. From this emerges the experience and knowledge that is acquired through the act of making. Applying this to my own work, through reflecting on my projects, has enabled me to better understand the act of making.

According to Schön (1988, pp. 182–83), designing is an act of making and the act of making is where ‘the designer constructs their design worlds not only through the shaping of materials but through interlocking processes of perception, cognition and notation’. This suggests the act of designing is a lived experience. Implicated in this lived experience is an embodied knowledge that emerges through a sensory awareness of the design situation and the materials used in the making process. This sensory awareness extends outward into the world through our actions, bound within the artifact the designer creates. I use the term ‘materials’ in a general manner, acknowledging it can be used to describe any ‘thing’ I apply in the process of making. Schön’s view of design practice is one that embraces a
phenomenological framework, where bodily sensations are the materials of knowledge. From this knowledge we acquire an understanding of our design process, through experience, perception and observation.

If we accept Schön’s view that what we create can be viewed a phenomenon like many other things we perceive within our environment (1983, p. 62), then the object we perceive is not a constant. Instead our relationship to the object is dynamic. It’s bound to our senses, our emotions, preferences and values, to what Schön refers to as our ‘appreciative systems’. This, in action, forms an important connection between our thoughts and our ways of doing when acting on the materials. This information feeds the process for designing, enabling the designer to construct judgments about the results of design decisions or actions.

According to Schön (1984, p. 32), problems are not givens; they come into existence because the designer, as well as others, may perceive them through the design moves made. The interconnection between a designer’s moves and the perception of the problem implicates an awareness of the situation as it evolves. For some thing to be considered a problem is to presume the designer knows something about the problem. Schön suggests that our understanding of a problem situation forms from our interaction with the materials. By allowing the materials to ‘talk back’ (Schön, 1988, p. 183) our understanding of what the problem is becomes acquired knowledge. When knowledge is applied to resolve the problem situation, the experience gained joins our repertoire of past experiences and can then be applied to future problematic situations. If a designer is aware of the problem, how does a designer respond to the problem?

Schön uses the term ‘reflection-in-action’ to describe a designer’s capacity to respond to a problem through their actions, by improvising with the materials. By framing the inquiry through the question “what if I did this?”, the designer is opening the process to then explore and learn more about the situation through iterative material transformations. In the context of architectural design practice, Schön refers to the iterative process as ‘seeing-doing-seeing’.
In principle this could also be applied to activities in sound design but in the form of ‘listening-doing-listening’. The iterative process informs the design by revealing a new situation that emerges from the design move. From this new situation, a new set of problems, a new response and a new move eventuate. ‘Knowing-in-action’ is what Schön describes what we know by intuitively responding to a problem situation and our knowledge of the situation is evidenced through our actions.

Acknowledging the act of reflection as a listening-doing-listening activity, then this can, in principle, be applied to almost any sound-related activities. It suggests a process in which the sound designer continually reflects and responds to what it is heard through an ongoing sequence involving material interaction. The instinctive actions of ‘knowing-in-action’ can be applied to the operation of audio devices or to enacting spatial gestures already learnt as an outcome of the reflection-in-action process. Understanding the context of these actions in the course of my practice, conveys a greater sense of meaning to what I do and what I know through a reflection of my own actions and how the materials’ I work with, respond to my actions.

From experience to concepts of space.

To understand what a thing is, is to work out the space suggested by the dimensions of that thing.

– François Bayle

In exploring the sound space relation, my research references the practice of phenomenology to emphasise the connection with the physical and imagined experience of sound and space. According to the practice of phenomenology, space is the passive field that lies between things and the field that unifies all things. From a sound perspective, Francois Bayle (2007, p. 243) suggests, the sense of space is perceived through the subtle transformations that occur within and between the projected planes, over time.
In acknowledging the sound experience is a temporal and spatial sensation, I use the terms homogeneous and heterogeneous, to convey a perceptual quality of space that sound occupies. Positioned at opposite ends of the rich spectrum of space perception, they describe the spatial and temporal relations I sense in the aural environment. The ‘homogeneous’ is the coherent and neutral experience of space, and the ‘heterogeneous’ is the complex and dynamic experience of space. I continually reflect on these two representations for guidance, superimposing them over my thoughts and actions to create my own spatial, musical interpretation.

**Imagined space.**

I use the term ‘imagined space’ to emphasise the connection between the sensation of sound and that of the hidden interior - beyond the physicality of the object. By exploring the hidden interior, I have attempted to engage with my own experience of sound within the environment. The intent is to engage with the sound experience and how a sense of reality can manifest from within the imagination. This relation can be extended to a process in sound composition, where sounds that share a similar quality can be used to activate a suggestion of space. This suggestion becomes a powerful device that can be used to transform our perception of what it is we actually hear. The following working note is an experience I recorded whilst travelling along the coast in 2011. It demonstrates how an imagined reality can manifest through an experience of sound:

> From my window I can hear the distant roar of the ocean. The rhythmic sounds of the collapsing waves reach a crescendo before disappearing from my hearing only to re-emerge moments later. I imagine myself there, standing on the water’s edge and I decide to investigate. On reaching the source I find that my senses have deceived me. What should be the ocean is in fact the sound of cars travelling along the motorway.
Emerging from this sensation of sound is an elastic connection that forms between my thoughts and actions. I create the space in which I place all things. My experience of the sounds of the ocean enables me to associate the qualities of the sound I was hearing, with that of the ocean. The sensation of sound is powerful enough to invoke a desire, create or even alter our view of reality. To apprehend this sensation as a form of knowledge, is to reduce the phenomenon to the level of concrete evidence. The process of verifying the source of the sound works in this way, where the elastic and dynamic connection once held within the mind is replaced by a physical reality. Accepting Merleau-Ponty’s view (1962, p. 284) that sensations are the materials of knowledge then sound, a spatial sensation we experience every day, can also be viewed as a material of knowledge. Once knowledge of the sensation is acquired, the sound sensation becomes an object of the physical world.

New York’s Washington Square is laid out as a regular rectangle, framed by houses on all sides – and yet it is not a ‘closed’ square. For its dimensions are so large, the proportions of many of its surrounding structures are so heterogeneous, so irregular, even contradictory, and the location of the small triumphal arch are so dissimilar to all other given factors that a unified impression cannot result. Disproportion in scale destroys all aesthetic possibilities.

– Paul Zucker (Arnheim, 1977)

Paul Zucker’s experience of New York’s Washington Square is an interesting introduction to the notion of the ‘heterogeneous’ experience. Zucker’s observation highlights the tensions that emerge from an experience of space that is void of any sense of coherence. From an architectural perspective, Zucker concentrates his response on the qualities that define a physical space: proximity, size, shape and proportion. But Zucker’s reflection also suggests the objects sensed, impose their own spatial context within the space. I use the term ‘heterogeneous’ to emphasise the dynamic and interchangeable nature of space, from the concrete to the imagined and vice versa. I consider the heterogeneous space to be one that
can be designed to awaken our senses, challenge our beliefs or offer a different view of our experiences of the world. The everyday experiences we take for granted or we no longer sense because we know them so well, can be brought to our attention. If every city square presented a form consistent with our experiences of city squares around the world, then it takes no greater degree of effort to understand its relationship to its surrounding environment.

The re-imagining and re-interpreting of coherent and real-world experiences is not new to contemporary art practices. Dziga Vertov’s avant-garde film *Man with a Movie Camera*, created in 1929, is one example of such an approach. Using film based editing techniques to cut, copy and merge multiple images, Vertov creates a new sense of space within the projected image. Another example in which the everyday experience of space is re-imagined, is expressed in the following extract from Laszlo Moholy-Nagy’s (*Nemeskürt, 1974*) film sketch *Dynamics of a Metropolis* (1921–22):

Building construction with an Iron Crane (Use of special trick effects-line drawing-melting slowly into the filming of nature)
Crane for construction:
  Shot from below
  Diagonally
  From above
  Elevator for bricks
  Revolving crane
This movement is continued by an automobile racing
  To the left. The same house is always seen
  In the centre of the picture.
(The house should always be re-photographed to place it in the centre.)
Another automobile appears which tears along at the same speed,
  but in the opposite direction.
  Tempo, tempo!
One row of houses rushes by in the same direction, always allowing the house in the middle to be seen. The row of houses runs past and comes back.
Rows of houses race transparently in opposite directions, and so do the automobiles. Faster and faster, so the audience is made dizzy.
  A tiger, TIGER walks about in his cage
  Walks back and forth angrily.
High up, clearly visible traffic signals.
Moving automatically
A-u-t-o-m-a-t-i-c-a-l-l-y
(close up)
In the example above, Moholy-Nagy poetically combines images of everyday objects and activities to create an experience of time and space not typically encountered in everyday life. In exploring the dynamic rhythms of the metropolis, Moholy-Nagy attempts to break from a tradition in film storytelling that tends to follow a linear plot. The juxtaposition of static images and the house shot at different perspectives is in itself a suggestion of space. The rapid movements of objects accentuate the passing of time. Their trajectories tracked across the screen matching the direction and speed of other moving objects. As images merge, the implied association links to a deeper meaning that is unlocked from within. The emphasis on rhythm and movement suggests a musical quality that pulses through the body of the work, as if the images are composed to the metronome of the machine. Both Moholy-Nagy and Vertov have re-imagined and recomposed the everyday visual experience through their own poetic interpretation. Having watched Man with a Movie Camera several times I am always surprised to see something new emerge from the screen. This I believe is one of the strengths of this medium as an art form, emphasised through a compositional intent that invites viewers on a journey in which they create their own story through the relation of image and movement.

Spatial music

The practice of acousmatic music reaches out to the listener, extending the experience of sound in much the same way as experimental films extend the experience of the image for the viewer. According to Francois Bayle (2007, p. 242), ‘acousmatics is the technique of making an awareness that is established simply and solely from facts of both an intuitive and a creative perception.’ I consider acousmatics an artform that aims to address our sensory modalities through sound, movement and live performance. The sense of space manifests through the process of sound diffusion, which I consider to be a combination of reflection-in-action and knowing-in-action. Where reflection-in-action is the process of ‘improvisation that consists on varying, combining and recombining a set of figures within the schema which
bounds and gives coherence to the performance’ (Schön, 1983). In the context of sound, the
sets of figures could be reinterpreted as the materials of sound, and the schema as the
spatial representation of the music within the performance space. The action of reflection
then becomes a listening-doing-listening activity, in which the response is almost immediate,
given our reflexes at the audio mixing console, but my point here is that the actions of spatial
reinterpretation evolve as we continually reflect and respond to what it is we hear as it is
projected into the performance space.

According to Bayle (2007, p. 2), to understand the space held within the projection of the
image, it is necessary to unveil the space within the sound. The suggestion of the sound
image is very different to the acoustic description, where the image of the sound source
occurs when the reflecting surface is larger than the wavelength of the incident sound. In the
context of acousmatic music, the notion of the image is linked to an affective imagined reality
that seeks to activate the senses through an experience. Supported by an electromagnetic
framework, being the use of loudspeaker technology to broadcast sound into space, the
experience of sound and its inhabited space, is projected beyond the dimensions of what is
perceived as natural or real. As Bayle (p. 241) says, ‘A sound that has come out from a
transducer is not a sound like all the rest.’ As a result, the projected image may reference the
sounds that exist in the natural world, like the sound of thunder or the sea, but the
interpretation of the sound and its space is suspended through a poetic re-imagination of
time and space that is activated local to the listener. The proposition of space is therefore not
one singular homogeneous image of space bound entirely by the electromagnetic framework
that delivers it but an affective experience reaching the listener’s ears through a succession
or patchwork of images that overlap in time and space, and shift in location, size and shape.

Physicality of sound

If we accept that sound is a pressure wave transmitted through the atmosphere, then in the
natural environment the pressure wave will interact with objects located within that region of
space. This physical interaction causes the wavefront to be modified and the degree of modification is dependent on the type of material it makes contact with, resulting in the reflection, diffusion and absorption of the wavefront. By the time the wavefront reaches our ears it may have made contact with numerous surfaces located within the space. At each point of contact the wavefront is broken up into smaller wavefronts and what we hear is a complex combination of both the direct and reflected intensities of the original sound source.

The number of possible pathways a wavefront may take to reach the listener is vast, given its interaction with the surrounding environment. Without interaction the shortest pathway from sound source to listener is called the ‘direct path’, as shown in Figure 2.

![Figure 2: Representation of a sound wavefront in a free-field space](image)

As a wavefront moves through the atmosphere its intensity is diminished due to the spreading of the wavefront moving outward and its interaction with the atmosphere. Intensity also decreases as the distance between sound source and listener increases. The intensity of a sound can be measured in decibels (dB), and the degree to which sound intensity decreases is referred to as the ‘inverse square law’. This states the drop in sound intensity is inversely proportional to the square of the distance. So, for every doubling of distance, the intensity of the sound is half its original power.
This is also true for wavefronts reaching our ears once reflected off surfaces in the environment. The surface qualities of an object can change how evenly a wavefront is reflected into space. A diffuse soundfield is the result of an even scattering of the wavefront, dissipating the intensity of the sound on contact. With a reverberant soundfield the shape of the wavefront is retained; however, it is continually broken up into smaller wavefronts as it is bounced back and forth between surrounding surfaces. A single-point reflection that occurs at the boundary is shown in Figure 3.

![Figure 3: Boundary interactions](image)

As the complex combinations of direct and reflected wavefronts reach our ears, we perceive multiple images of the original sound source. The image of the sound source occurs when the reflecting surface is larger than the wavelength of the incident sound. Images that reach our ears within the first 40 milliseconds are masked by the intensity of the initial direct wavefront. This is called the 'precedence effect'; a psychoacoustic phenomenon that holds true, provided, the intensity of the direct wavefront is greater than the reflected intensity.
Wavefronts that reach our ears after the first 40 milliseconds are perceived as echoes. Echoes are the repetition of a sound due to reflection. The differences in intensity and time of the wavefront play an important role in spatial perception, the cognitive process for locating a sound's spatial position in a space. Blesser (2001, p. 868) describes an echo as the sonic manifestation of a sounding object. This suggests that once it reaches our ears the reflected wavefront is almost an exact mirror image of the actual sounding object. If the delayed intensity of the reflecting wavefront is equivalent in size to the direct wavefront, then our perception of the sound source location shifts slightly toward the direction of the reflected image. This shift is due to phasing, the differences in both intensity and timing between the original and delayed signal. By suppressing the direct wavefront, leaving only the reflected, then applying the principle of the precedence effect, our perception of the sound source location shifts to the direction of the reflected image. This is a psychoacoustic phenomenon, which is often referred to as a sound source image, or virtual image. For the sound source image to hold, the image needs to be stable. A stable image occurs when the combined sum of reflected wavefronts match as they reach our ears, forming a coherent reconstruction of the original source. I have often observed this phenomenon in the city, where tall buildings offer large reflecting surfaces but at the same time occlude the sound source giving the impression that the sound source is located in the direction of the reflecting surface.

The location of a sound in a three-dimensional space can be broken down into angular components – azimuth and elevation – where the point of origin is located at the centre of the listener's head, as shown in Figure 4. The azimuth locates the position along the horizontal plane, and elevation along the vertical plane. The subtle differences in time, intensity and spectral information reaching our ears, play an important role in determining the location of a sound in a space. This is referred to as sound localisation. Sound localisation is a psychoacoustic phenomenon that describes our ability to extract spatial information from the sounds we hear via our auditory system. The mechanisms of sound localisation are described through auditory cues, including interaural time differences (ITD), interaural level differences (ILD) and differences in spectral information.
When a sound source is positioned on the horizontal plane either to the left or right side of the head, the wavefront will generally reach one ear before the other. As the head carries mass, the wavefront interacts in much the same way as other objects in the environment. Sound is absorbed and diffracted as it is transmitted through the head, and the ITD is a measure of the time difference for the sound to travel from one ear to the other. Also, the intensity of the wavefront reaching the first ear will be greater than that at the other ear. The ILD is a measure of level differences at both ears due to the absorption of incident sound and the occlusion of the wavefront around the head. For sounds positioned directly in front or to the rear of the head, the time and level difference between both ears is near negligible, and the location of the sound is determined by a difference in spectral information due to the physical shape of the ear. This allows the listener to discriminate sounds positioned directly behind the head by changes in spectral intensity. In the context of sound localisation, sound level differences assist with the position of a sound on the azimuth, time differences assist with distance perception, and frequency differences assist with elevation.

Figure 4: Location of a single sound source in a virtual 3D space

Malham (1988, p. 167) states there are two types of homogeneous soundfields: real and synthesised. A real homogeneous soundfield is something we experience in our everyday
lives. A natural soundfield surrounding the listener does not preferentially treat sound in any
direction. A synthesised homogeneous soundfield refers to a reproduced soundfield using
electroacoustic techniques. Loudspeaker reproduction systems driven by ambisonic or
wavefield synthesis techniques (WFS) are examples of synthesised soundfields that are near
homogeneous. These techniques are considered near homogeneous because the soundfield
is not a complete reconstruction but instead a close approximation of one. In general,
ambisonics and wavefield synthesis are both holophonic techniques that reconstruct a
soundfield by simulating a three-dimensional wavefront that surrounds the listener using
large loudspeaker arrays.

The built environment

Within the context of the built environment, I use the concert hall as a vehicle to discuss the
qualities of a listening space that is highly tuned for the purpose of controlling sound.
Conceptually, the concert hall represents a way of working with physical materials and
geometry to create a space, which in terms of an experience of sound, can be considered
homogeneous.

Sound energy emitted from a single source within a room is
characterized as a homogeneous field, distributed uniformly
throughout space, gradually and uniformly absorbed by the
surfaces to which it is exposed.

– Wallace Sabine (Thompson, 1997, p. 603)

Wallace Sabine’s description of the behaviour of sound in a space is a conventional view of
sound propagation, where the notion of the homogeneous soundfield is considered a
completely diffuse field. Based on a spherical model, the transmission of sound from a single
point source travels through the atmosphere, absorbed and reflected as it comes into contact
with the various objects within its path. Much of Sabine’s work in the field of acoustics was to
better understand the relationship between the materials of the built environment and the
behaviour of sound within an enclosed space. Emphasis was placed on sound reverberation and the design of high-performance listening spaces such as concert halls, theatres and opera houses. As Sabine found, the type of material, its density and the volume of material used, directly influence the surface interaction between the soundwave and the material through reflection and absorption. According to Michael Barron (1993, p. 41), a well-designed concert hall should stimulate the auditory senses, giving the listener a sense of intimacy and a sense of envelopment. The sense of intimacy relates to the clarity of sound, and envelopment relates to the perception of spaciousness.

Up until the 1900s, the tools available to architects for designing a performance space that presented the listener with a sense of intimacy and spaciousness, were limited; that is, the knowledge for predicting how sound performed within the built environment was still in its infancy. It was only with the publication of Sabine’s solution for determining room reverberation circa 1900 that a noticeable shift in architectural practice occurred. With this new knowledge, architects were not only able to predict precisely the acoustic conditions of a space, but determine the exact dimensions of a hall required to achieve a particular reverberation quality. Effort was then invested correcting poor design in previously built concert halls in order to rectify their acoustic problems (Watson, 1914, p. 4).

In contemporary architectural practice, Barron suggests two possible approaches for designing concert halls. The first approach applies an acoustic model and considers the physical interaction between sound as a wavefront and the physical materials of the build environment. The second approach focuses on the auditory perception of sound, or, the ‘space between the ears’. In both approaches, a theoretical precedence is established for understanding the link between the physical space, the behaviour of sound in a space and the subjective values that determine if a sound in a space is good or bad. Both approaches attempt to solve the same complex multidimensional problem but in very different ways. In the context of my research, both are considered homogeneous approaches in their application of reduction techniques.
In the case of the acoustic approach, there are two types of spaces often considered: enclosed and free-field. An enclosed space is constrained by four walls, a floor and a ceiling. The physical properties of the materials and the geometry of the space, is considered within a mathematical relationship for determining the acoustic behaviour of sound within the model. Comparatively, the behaviour of sound within a free-field space is considered to be far more complex than in the case of an enclosed space. This is due to boundary effects as the wavefront is modified at the material's surface, which in an open space such as an outdoor setting could easily contain an infinitely complex variety of materials in an equally diverse set of configurations. In the case of the auditory approach, the listener’s physiological response to sound is central to the study and the use of anechoic chambers and electroacoustic loudspeaker arrays is established practice within this field. Subjective qualities for sound in space have been linked to their associated acoustic qualities, and models for spatial hearing have been developed from subjective listening tests. The subjective qualities most important to architectural design relate to the sense of clarity, reverberation, spatial impression, intimacy and loudness (Barron, 1993, p. 41).

According to Percy Buck (1918, p. 10), ‘when a man sets out to study the Art of Music he is, in all probability, under the impression that he is dealing with a homogeneous and isolated subject; but before long he will be forced to realize that his study, if it is to be in any sense far-reaching, must embrace a great number of subjects each of which is in itself merely a subsidiary and component part of a wide and comprehensive whole.’ By reducing a multidimensional problem to fundamental objective components, the homogeneous representation is limited in its capacity to translate across a wide range of scenarios. Moving beyond the boundaries of the homogeneous system often results in discontinuities and the criteria established for describing that system are no longer applicable. Resolving the problem of the new condition therefore requires a new way of interpreting the scenario.
An example of this occurred in the 1930s. Advances in material manufacturing and the introduction of electroacoustic techniques, shifted our way of thinking about the acoustic environment. As Emily Thompson points out (1997, p. 609), even though Sabine’s method for predicting reverberation times within rooms was a significant advance for architecture, it failed to accommodate for rooms that were treated with sound-absorption materials. Material manufacturing had advanced to a point where sound-absorbing materials could be produced in much greater quantities than previously possible. New techniques started to change the way buildings were constructed and architects could choose from a wide range of building materials. In the film and radio broadcasting industry, quiet recording studios were a necessity. Room construction started incorporating highly treated absorbing materials and the boundaries of architectural space became inconsequential as mechanical acoustic techniques moved to electroacoustic.

Electroacoustic techniques, not walls or floors, were employed to create the sensation of space. Electroacoustic recording and reproduction techniques and the use of loudspeaker technology offered a different approach to the design of the soundfield within a physical space. They reduced the need for the built environment to provide acoustic solutions. In 1930, after revisiting Sabine’s calculation for reverberation, Carl Eyring established a mathematical model describing sound reverberation in a space. In Eyring’s model, the reflection of sound was represented by an infinite number of virtual sound sources located at varying distances around the original sound source. In this context Sabine’s earlier conception of sound reverberation within enclosed spaces, emitted from a single point source and reflected back into the space, moved to a model of sound in a free-field space, supported by an electroacoustic framework.

By 1940 technological advances in radio broadcasting enabled composers to capture and manipulate sound in much the same way film editors work with the visual medium. As Stockhausen (1960, p. 40) writes, ‘I found, for the first time, ways to bring all properties (of sound) under a single control. I deduced that all differences of acoustic perception can be
traced to differences in the temporal structure of sound waves.’ The temporal qualities of sound can be realigned against their associated acoustic dimensions, frequency, time and amplitude. Sound, the once fleeting sensation, could be captured or synthesised, deconstructed and reconstructed based on acoustic laws in which the perception of the sound event is considered the sum of all its individual acoustic properties.
Homogeneity and Heterogeneity

I refer to the notion of the ‘homogeneous’ as captured by David Malham (1988, p. 167) in which he states, ‘a real homogeneous soundfield is something we experience in our everyday lives’. The idea the ‘homogeneous’ soundfield is one that does not preferentially treat sound in any direction, is based on a physical system that describes how sound interacts with the surrounding environment. In this context, the wavefronts that reach our ears come from all directions, not just one. Malham’s suggestion of the ‘everyday’ implies the ‘homogeneous’ sound experience is a shared experience, which is brought to our awareness through the physicality of the environment. I refer to the notion of the ‘heterogeneous’ as captured by Paul Zucker, which speaks in opposition to the coherent, ‘homogeneous’ experience and can be used to describe a scenario in which an experience of sound within the physical environment is new for the listener.

In acknowledging the physical connection with the sound experience, I also adopt the ‘homogeneous’ and ‘heterogeneous’ terms to embody the essence of a compositional methodology that is guided by a spatial and musical aesthetic. Spatial music practices that use multichannel reproduction systems, can, in principle, recreate a sound space that embodies the spatial and temporal qualities we perceive within the real-world environment. By combining spatial sound reproduction systems with audio signal processing and spatial mixing techniques, it is possible to use these techniques to reconstruct a sound space that embodies ‘homogeneous’ qualities. In principle, the same techniques can also be used to reproduced a sound space that embodies ‘heterogeneous’ qualities. This chapter will discuss how spatial sound techniques can be applied in the process of sound composition to convey a spatial sound experience that embodies ‘homogeneous’ or ‘heterogeneous’ qualities.
Audio signal processing and editing

Applying audio signal processing techniques to modify the spatial or temporal qualities of a sound, is useful when attempting to enhance, or extend, the qualities that are most appealing. In the context of a compositional approach, to understand why this process is important, I refer to Bregmans account of auditory steaming (1994, p. 324), which accounts for our cognitive ability to comprehend a complex soundfield by grouping sounds into coherent entities, or 'streams'. This ability enables the listener to discriminate between sounds based on their organization within the 'stream'. On this basis, the perceptual organisation of sounds is an important facet of the sound editing process. It enables the sound designer to use sound editing and compositing techniques to sculpt sound in ways that help guide the listeners' attention toward specific sound elements within the composition. The techniques applied in this process are used to address a number of key perceptual characteristics that include, spectral shape, spatial location, intensity and noise.

Spectral shape relates to the organization of frequency components that make up the internal structure of a sound - the space within sound. A spectral mixing technique, such as convolution, can be used to modify this internal structure by multiplying the frequency components of two source sounds together to create a new sound structure. As a result, the organization of the frequency components within this new structure follows a similar pattern that is observed within each of two source sounds. As Denis Smalley (1997, p. 107) describes, convolution is a process that can be used to impose the space of one sound onto another sound. By applying spectral mixing techniques in the sound editing process, the sound designer can also convey to the listener an impression of physical space. This process can be achieved by using convolution to recreate real acoustic spaces that are, perceptually, far more realistic than most reverb effects. From an artistic perspective, by combining spectral mixing techniques with more traditional digital editing techniques, such as the ability to cut copy and paste sound materials along the time domain, this process becomes a powerful device that can be used to transform the listeners’ perception of space and sound.
over time. When coupled to a spatial movement, sound takes on another dimension, occupying a space that can be shared with more than one listener.

**Two techniques for sound spatialisation**

Our ability to localise sound in space is dependent on a number of auditory cues which, as discussed in chapter 1, (p24), are measurable qualities used to describe perceptual differences in the properties of sound reaching our ears: time, loudness and timbre. These qualities are important in spatial sound reproduction; where the listening experience is contextualised by a process that attempts to reproduce the spatial qualities experienced within a concert performance (Malham, 1988, p. 170). In this context, spatial mixing is an activity that is generally performed in a studio and it involves the positioning of recorded sound sources within a spatial field, such that it mirrors the arrangement observed in performance. In terms of stereophonic sound reproduction, which is more suited to the home listening environment, sound localization is restricted to a stereophonic soundfield, with sounds panned within that field. This technique does not attempt to recreate a true spatial soundfield, however, sensing the differences in timing and loudness between two loudspeakers is enough to create a virtual image, which for the listener, appears at an angular point in space between the two loudspeakers.

The virtual image is an auditory phenomenon that is perceived when the listener is located within the stereophonic sweet spot. For the virtual image to remain stable, loudspeakers must be in front of the listener and separated by 60 degrees or less. This technique performs poorly when loudspeakers are positioned to the rear and to the sides of the listener, due to a lack of coherence between the perceived qualities of sound. The stereophonic format is also limited in its capacity to hold the spatial information required to reproduce a true surround soundfield. Pair-wise mixing however, a technique used in the practice of sound diffusion, extends stereophonic reproduction techniques and applies it to a spatial reproduction system that uses multiple loudspeakers instead of just two. As a technique for spatial sound
reproduction, pair-wise mixing is also limited in its capacity to reproduce a true surround soundfield as it also uses a stereophonic format.

Ambisonics is another spatialisation technique that is used in spatial sound reproduction. Ambisonics is a matrix mixing technique developed by Michael Gerzon and others, from the Mathematical Institute based in Oxford around the early 1970’s (Gerzon, 1974). Used in sound production for capturing and reproducing a three-dimensional soundfield, this process can be generalised by a two-stage process that involves audio signal encoding and decoding. The process of ambisonic recording uses an ambisonic microphone, which contains four large diaphragm capsules geometrically arranged in a tetrahedral configuration. Generating a four-channel A-format audio signal, each of the four signals contains phase and amplitude information unique to the spatial arrangement of each capsule. Each of the four channels within the B-format stream is referred to as the WXY and Z components. W is referred to as the Omni channel and the X Y and Z relate to their respective Cartesian relationships and these components are directly linked to the orders calculated within the spherical harmonic domain.

The multichannel signal is then sent via an encoding stage and matrix mixed to create a B-format multichannel audio stream. The B-format signal is then sent via a decoding stage which, based on the spatial location of loudspeakers within the space, is used to create discrete audio-signal feeds for each loudspeaker. Reconstructing the soundfield over loudspeakers, creates a stable virtual image regardless of the listener’s location within the loudspeaker arrangement. In principle, the process of ambisonic synthesis works in the same way, but without sound capture using an ambisonic microphone. Instead this process is enabled using software tools, where a single monophonic audio signal is coupled to a virtual point in space as part of the encoding process and then decoded, using the same principles mentioned above, before it is projected into space over loudspeakers to reconstruct the soundfield.
Spatial sound reproduction

Commercial music purchased online or on compact disc use a stereophonic format, which in terms of the technology required to access the musical content, is relatively easy to obtain for most consumers. On the most basic level, a stereophonic playback system consists of a media player, amplifier and a pair of loudspeakers. Comparatively, multichannel reproduction formats contain more than two discrete audio signal channels and this requires the playback system to be scaled-up. The process of scaling-up a reproduction system often requires; increasing the number of loudspeakers and changing the type of playback equipment needed to address the additional channels. The multi-channel medium is attractive in terms of the surround sound experience it can offer to listeners given multiple layers of a composition can move independently in space, however, increasing the capacity of the playback system also introduces a number of important considerations which, in terms of the listening experience, need to be addressed. These relate to the location and direction of loudspeakers, audience seating arrangements and the acoustic qualities of the listening space. As Stockhausen states;

You come into a hall for the first time and set up for an entire day, before the musicians begin rehearsals on the following day, and the first question arises: Where should the loudspeakers be placed? The first year, you will only know approximately what is best, and you will experiment around. After many concerts, you know a little better; but you can never foresee quite exactly what the best solution really is. So, you move the tripods, change the suspension, roam about the hall for hours, until by evening you are at last ready to play back a test-tape and have the feeling, I now have the hall under control.

- Karlheinz Stockhausen (1994, p.84)

In July 2008, I attended the Stockhausen Tonmeister course in Keurten, Germany. The course covered all aspects of Stockhausens’ performance techniques, including microphone placement, evaluating acoustic space, spatial sound projection and loudspeaker
configurations. From first impressions, Stockhausen’s loudspeaker configurations can be a little puzzling, where, positioned at every loudspeaker location, two loudspeakers are situated side-by-side and facing into the audience seating area. For *OCTOPHONIE (1989)*, an 8-channel tape piece, a total of 16-loudspeakers are required for playback and this is not including subwoofers. What may seem a strange decision is in fact, a considered approach that addresses a fundamental problem when using loudspeaker systems for the projection of sound. It relates to the perception of sound in space and how the listening experience can vary depending on the listeners’ location within the performance space. Even though Stockhausen’s spatial mixing technique is beyond the scope of my research, having the opportunity to engage with his tape music projected over loudspeakers, it is clear to understand that the surround sound experience is a crucial component that defines Stockhausen’s musical practice.

With the focus placed on the spatial sound experience, then the process of identifying the best locations for loudspeakers becomes an important aspect of the spatial music practice. As Stockhausen suggests, knowing the balance between sound and space is learnt through an ongoing process of experimentation and listening. The experience and knowledge gained from this process joins our repertoire of past experiences. This can then be applied to future situations to address the qualities of the listening experience that relate to fidelity, a sense of clarity and spaciousness. Finding this balance can be a complex process, as these qualities will vary depending on the acoustic conditions of the performance space and the listeners’ location, relative to loudspeaker locations, within the performance space.

‘Clarity’ is a quality of coherence and intelligibility and describes the ability to hear sound clearly. Sound clarity can degrade given unfavourable acoustic conditions, such as highly reverberant spaces, or environments that have excessive background noise. Sound clarity can be improved by combining techniques to reduce the effect of reverberation, such as placing sound absorbing materials around the performance space and by moving the loudspeaker configuration in, closer to the listener. By applying these techniques, the effect will increase
the ratio of direct sound energy against reflected energy. Even though some reverberation can enhance musical qualities, my point here is that the degree of any change should be measured against a desired musical aesthetic.

‘Spaciousness’ is a term used to describe the physical qualities of space, in terms of its size and volume. To better describe this auditory phenomenon, spaciousness is also defined by a measurable parameter, the apparent source width (ASW). As Keith Yates states (2009), the ASW is ‘related to the perceived level at the listener’s ears, the lateral reflections in the first 50 to 80 milliseconds after the arrival of the direct sound’. By increasing the ratio of reflected energy against the direct sound within this time frame, increases our sense of ‘spaciousness’.

The sense of spaciousness can be achieved by placing loudspeakers directly to the left and right sides of the listener, or, by using the physical features of the performance space as a reflecting surface. In the first instance, with loudspeakers placed to the sides and aimed towards the listener, the timing of the reproduced sound needs to be delayed by 50ms to 80ms relative to the direct sound for the effect to perform. In the latter scenario, loudspeakers are directed towards the surfaces of the performance space. The distance required for the sound to travel toward the reflecting surface and then to the listener, is longer than the distance traveled by the direct sound. By extending the physical path sound has to travel to get to the listener, increases the amount of time taken but at the same time, reduces the intensity of the sound as it interacts with the space. This technique is often used in sound diffusion, where the space offers physical solutions for modifying the temporal and spatial qualities of sound before it reaches the listener.

In the context of the spatial sound experience and the notions of the ‘homogeneous’ and ‘heterogeneous’, we can consider our choice of spatialisation technique based on the fidelity of the reproduction, where ‘fidelity’ relates to how true the reproduced sound is to its source. On this basis, the stereophonic technique can only reproduce a partial soundfield that is effective for a small number of listeners located within the stereo field. Pair-wise mixing is a technique that extends the stereophonic image, but for a larger number of listeners by using
multiple loudspeakers positioned around the space. By emphasizing the perceptual
differences in the reproduced sound, the technique has a desired effect that widens the
stereophonic image. Applying this technique can also convey a sense of spaciousness, but
like stereophonic sound reproduction, the technique can only create a partial surround
soundfield. An advantage of this technique is that it is scalable and the loudspeaker
configuration can be shaped to any geometry. Ambisonics is a technique that can reproduce
a full surround soundfield with a high degree of precision. The technique is flexible for any
number of loudspeakers and performs best when they conform to balanced geometric
configuration.

In acknowledging performances spaces can vary in terms of their size and shape, then by
changing the location and directionality of loudspeakers will affect how the listener perceives
the intensity of sound that is distributed to each loudspeaker. Loudspeakers located close to
and directed towards the listeners’ position can sometimes mask the output signal of an
adjacent loudspeaker that is further and directed away from the listener. This is due to the
precedence effect, and this can create problems for the listener, where the sense of the
spatial image can degrade. The ambisonic technique can overcome this problem by using
loudspeakers that are matched in size and quality and by ensuring loudspeakers are always
directed towards the listener and positioned in a balanced geometric configuration around the
listener. Pair-wise mixing can also overcome the problem by ensuring loudspeakers maintain
a paired configuration, for stereophonic imaging to work, and by actively modulating the
intensity of sound at each of the loudspeakers to create a desired experience for the listener
within the space.

By applying this knowledge to my own compositional work, has enabled me to better
understand how the notions of the ‘homogeneous’ and ‘heterogeneous’ can be used to
embody a compositional process. Furthermore, this process can be explored through the
techniques of spatial mixing and sound processing to reproduce the sonic qualities a listener
experiences within the real-world environment.
Projects: two approaches

In the same way we appreciate a landscape in a storm, the force of the wind on the trees, the whirlwinds, we find ourselves alert and sensitive to the harmony of movements that at the same time are chaotic yet geometrically ordered. Just as things occur, exist and break down into their parts, objects in time, in space, and so on.

– François Bayle

This chapter is an account of my projects, created and realised between 2006 and 2009 and presented in the order in which they were created. In this chapter I discuss my project Metamorphosis42 as a heterogeneous approach to sound design and my work Pilate as a homogeneous approach. I describe my projects by starting with an outline of the artistic intentions, the concepts and my motivations for engaging with each project. I describe in detail the process of making and the execution of each project. I conclude the section with a discussion about the application of the homogeneous and heterogeneous concepts embodied within each work. Table 1 lists the dates both works were created and performed, as well as the spaces in which they were performed to a public audience. Both projects were presentation over an eight-channel loudspeaker system.

Table 1: List of works

<table>
<thead>
<tr>
<th>Project</th>
<th>Created</th>
<th>Performed</th>
<th>Space</th>
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</thead>
<tbody>
<tr>
<td>Pilate</td>
<td>21 Feb – 3 May 2006</td>
<td>3 May 2006</td>
<td>BMW Edge, Federation Square, Melbourne</td>
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Pilate: a homogeneous approach

While little is known of Pontius Pilate we do know that he had more to fear from the socio-political unrest in Rome, than from the uprising in Judea. His close association with Sejanus, a man described by Tacitus as cunning and deceitful with an unbounded lust for power, gives us a possible insight into Pilate’s character. After the arrest and execution of Sejanus for treason, Rome was intent on the elimination of his family and supporters. No doubt this would have caused a great deal of consternation for Pilate. After his recall to Rome, Pontius Pilate disappears completely from the historical record.

– Jeffrey Hannam, artist statement for Pilate (2006)

Background

After reading The Annals of Imperial Rome by Tacitus, I was intrigued by a small story that describes a power struggle within the Roman ranks in which a man by the name of Sejanus attempts to cripple the regime through a subtle undermining of the senate and manipulation of the emperor’s will. In the end the story for Sejanus and his collaborators goes horribly wrong. What follows is a lengthy and brutal process of trial and execution in which anyone associated with Sejanus is a target regardless of the evidence for or against them. The implication of Pontius Pilate in the matter is debatable; however, historical records show that he was a close friend of Sejanus. Pilate is a multichannel work that takes the listener on an imagined journey through the mind of Pontius Pilate.

The story begins in the place in which Pilate lived. Archaeological evidence has shown that Caesarea Maritima was once an important administrative centre and official residence of Pontius Pilate. Situated along the coastline is an amphitheatre, which to this day looks out to sea from Caesarea Maritima. The location of the site played an important role in the conceptual development of the work. This amphitheatre grounded the story, giving it a sense of place, but it also inspired the drama that was to unfold in my imagination. From the
amphitheatre looking out to sea, an unobstructed connection forms between the heavens, earth and mind. The following extract from a working note (2006) is a rough sketch that explores this journey:

Phoebus strides across the heavens before plunging deep into the Mediterranean Sea. From Herod’s amphitheatre Pilate watches as a great tidal wave forms. Within seconds it will reach the coast of Caesarea Maritima. Heavy storms begin to move in, reinforcing Phoebus’s work, stretching out across the horizon. Little can be done to stop the torrential flow. The waters carry with them the memories of misguided agendas and the voices of the accused. Soon he too will fall and with him all trace of his existence will vanish, washed away.

The narrative outlines a series of events that are also reflected in the musical structure. The journey begins in the heavens as we travel with Phoebus, surrounded by the celestial bodies that glide in and around the space. Crashing into the sea we are left with the sound of waves hitting an imaginary beach. As the sound of waves subside, the listener is immersed within a sparse and eerie landscape. The sense of space closes in and as the density of sounds increases, we enter into the tormented mind of Pilate.

The process of sound spatialisation was enabled using MaxMSP4.6 and a suite of ambisonic objects freely available from the Institute for Computer Music and Sound Technology (ICST) website. The editing sounds was performed in Audacity and the mixing of audio was achieved using the digital audio workstation Logic Audio Pro 7. The materials used for Pilate include monophonic instrument recordings, studio voice recordings and a number of previously obtained field recordings.

All compositional work was performed in the Spatial Information Architecture Laboratory (SIAL) Sound Pod Studio. The Pod is a quiet studio-controlled environment with access to a sturdy grid and eight Genelec 1032A active loudspeakers that can be positioned in any
configuration around the space. The loudspeakers were patched to a MOTU896 multichannel interface, which was then connected via firewire 400 extension to the main computer console with a suite of installed audio applications used for driving the system. For Pilate, I used a cubic loudspeaker arrangement: four 1032A loudspeakers in a quad arrangement on the floor and four equivalent speakers placed directly above in the grid. The image below shows a 3D cutaway model of the Pod studio with view from the side on the left, and rear on the right.

Figure 5: 3D model and cutaway of SIAL Sound Pod Studio.

Approach

I recall visiting an online music forum in which the opening question to the thread ponders an approach for starting a musical composition. Do you start by creating the bass track first or do you start with the drums? The question made me think about my own approach to music. I have always found that finding a general mood or feeling has been a good place for me to start with any composition. From there, the types of sounds I first create in my head slowly find their way into the world through an exploratory process involving experimentation and making. Over time these sounds tend to fall into place like a puzzle, but, even so, much material is discarded along the way.
The following table provides a general overview of my studio workflow, beginning with the themes for each of the sections.

Table 2: Studio workflow

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<tr>
<td>2b. Rendering of monophonic sound files</td>
<td>3b. Signal processing</td>
<td>4b. Layers spatially decoded</td>
<td></td>
<td>5b. Final mix down to 8-channel playback</td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>3c. Rendering of monophonic sound files</td>
<td></td>
<td>4c. Rendering 8-channel file</td>
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Themes

The music is divided into three sections and given to each the following themes: Heaven, Earth and Mind. Each theme is symbolic of a particular spatial environment – sparse, grounded and chaotic – and as I progressed into the depths of the work, the themes often linked me back to my original idea, the imagined place and the narrative that framed the work. The following image shows the overall duration of the piece, with individual durations of each theme and a general transition between each theme.

![Figure 6: Duration of Pilate and themes](image-url)
Heaven is an expansive body, so the general mood needed to be light, conveying an impression of sounds moving freely around the listening space. In this section the sounds are of celestial bodies slowly rotating in a spiral trajectory around the central axis of the virtual environment. The density of sounds has been kept to a minimum, creating a sparse, nebulous texture. Each celestial body begins its journey moving in from the boundaries and into the space, above the listener’s head. The central axis for each body is offset and rotated, and the direction, for some, reversed to give variations in sound movement. Emphasis is placed on the perceived distance between the listener and the bodies by playing with the intensity, pitch and timbre of the sounds as they move in and out of the listening space.

The mood for Earth is heavier. Sounds are grounded and their locations and movements are constrained between the height of the listener’s head and the floor. The journey to Earth for the listener begins with the sound of Phoebus plunging into the sea. Sounds include extracts of recordings of natural sounds and events taken from a number of field recordings during a camping trip to Croajingolong National Park: the beach, crashing waves, falling rocks and snapping branches. As the sounds of the waves subside, the surrounding environment is very different in shape and texture. Percussive sounds begin to emerge, arching around the space in wide rapid trajectories followed by the sounds of voices, suspended at the edges of the space at the height of the listener’s head. The voices first appear as whispers. Clarity is suppressed by drastically rolling off the higher frequencies, playing with the idea of sound transmitted through the walls of an unseen space.

Earth merges into Mind. My intention for Mind was to draw the sounds of the environment right up against the listener. The clarity of the voices changes dramatically, suggesting the person now speaking is situated in the same space as the listener. The percussive beating gradually becomes louder and the density of sounds increases, resulting in a crescendo that ends with the thunderous applause from the heavens. All sounds, with exception of the thunder, are positioned directly at the height of the listener’s head. Sounds have an
immediate presence in the listening space and so the play in intensity, pitch and timbre is not heavily processed to the same extent as the sounds in Earth or Heaven.

Sound recording and editing

In an interview with Denis Smalley, Larry Austin (2000, p.10) asked what the strategy was for coupling sound materials against spatial gestures, to which Smalley replied, ‘materials hint at what to do’. Smalley’s response draws the importance of the listening process directly into focus and suggests an approach for better understanding the morphology of the sound, using a combination of visual and spectral techniques. All instrument and vocal recordings were monophonic, captured using a single Rhode NT5 cardioid microphone and streamed directly to computer hard disk for editing and processing. Sound materials were pooled into two folders: primary and secondary. Primary folder materials were directly implemented within the structure of the music, requiring little change or modification before use. These included natural sounds such as ocean, wind and thunder. Secondary folder materials were small sound files that were used for spectral processing purposes. Secondary folder materials carry a particular musical quality that I used to seed the creation of new materials or enhance certain characteristics in primary sounds. Secondary folder materials include samples of ice cracking, metal scraping, violin and rock slides.

For Heaven, the search for materials started by trawling through the banks of my Yamaha An1x synthesiser for the right type of sound to use. In the end the factory sounds that ship with the synthesiser were deleted and I began to work on creating my own sounds. For this I used a program called An1xEdit, an extremely useful application with a friendly interface for accessing and manipulating the synthesiser’s various on-board parameters and scenes. Of the work spent trialing and listening to sounds, only one audio recording was used from the instrument. It is referred to in my notes, and in the naming of the sound file, as An1x78. The value ‘78’ references the bank in which the sound was stored.
The sound was played out as a series of single random notes. I was attracted to this particular sound by an immediate sense of complexity and richness that seemed to vary depending on the velocity and pitch sequence of notes played. Compared to other sounds I’ve created, which tend to mimic the sounds of musical instruments, An1x78 is almost like the sound of a brick being dragged across a cement surface. On releasing the note, other less obvious voices started emerging from out of the spectral soup to dominate the listening space. On closer inspection of the melodic spectrum, the sound reveals an interesting internal structure that suggests an ongoing repetition across the entire spectrum. The shape, however, tends to differ in levels of immediacy depending on the velocity and pitch of notes struck. As one form is suppressed another emerges throughout the life of the note. The original length of the recording lasts just under 7 minutes.

In Figure 7, the four highlighted sections (A to D) show some key features that appear throughout the life of the recording. These vary depending on the pitch and the velocity of the note. Section A shows the horizontal segmentation of the spectrum every 150Hz and a clustering of frequency bands that become more diffuse as the frequency increases. Section B shows a distinct vertical segmentation of equivalent duration, a subtle repetition of the spectrum as the sounds decay. This vertical segmentation is clearly heard in the material as a constant pulsating effect that dominates throughout the entire sound.

Section C shows the relative densities of frequencies across the spectrum between two successive striking of notes. The first strike is clearly articulated by the separation between the bands across the spectrum. The second strike is much more condensed toward mid and lower frequencies. Section D suggests a complex harmonic relationship as successive frequency bands are compressed, creating the distinct streaking across the image. I found this quite interesting, as it is suggestive of a choir hidden within the structure. The hidden choir can be heard at various points in the sound file, sometimes dominating the space within the sound and other times emerging ever so softly from the turbulent mix of sound.
Signal processing

The process of sound modification in my work, is useful when attempting to enhance or extend the qualities of sound I find most appealing. My approach to any modification process begins with a series of small studies. This helps to contain the activities and the results of the work, to a small but, manageable set of explorations. When working in this way my aim is to refine my approach, to better understand the process and the parameters for working, but to also draw a sense of immediacy between my thoughts and actions and the process of modifying sound. For Pilate, convolution, granular synthesis and amplitude modulation were the signal modification techniques predominantly used.

In creating the sounds in Heaven, my approach was inspired by Bregman’s account of auditory streaming (1994, p. 324). Auditory streaming accounts for our cognitive ability to comprehend a complex soundfield by grouping sounds into coherent entities, or ‘streams’. Bregman describes auditory streaming as the perceptual organisation of sounds, and this organisation is one that typically follows a sequential order. To retain the cohesion of sounds within a single stream, sequential organisation is dependant on a number of key perceptual factors: spectral shape, spatial angle, intensity and noise. By reducing the relative differences
between sounds on each of the key perceptual factors, it is possible to ensure the stream retains its cohesion. Applying this knowledge to my compositional approach presented a way for me to engage with the process of creating new sounds from a much deeper level.

In addressing the characteristics of the auditory stream, I used convolution - a spectral processing technique achieved using a software application called SoundHack (Erbe, 2013). SoundHack offers a number of methodologies for transforming the internal morphology of sound. It is a program I have always used sparingly, as a great deal of time can be spent sifting through the bone yard of folders littered with audio files, that not longer make any real sense. SoundHack was used to convolve the An1x78 sound file with a sequence of recorded violin notes generated from a program called Reason.

Smalley (1997, p. 107) describes convolution as a process for imposing the space of one sound onto another. Convolution is a spectral processing technique that requires two input sound files: a source and an impulse. The source and impulse sound files are decomposed into a series of discrete segments called ‘bins’. Each bin of the source is then multiplied and shifted by the number of impulse bins. Figure 8 shows a comparison that shows the spectrum of the source, impulse and resulting output that is a blend of source and impulse. The horizontal and vertical segmentation is clearly visible in the convolved sound file’s spectrum; however, the bands are much softer than the original. In addition, the impression of the violin’s pitch material is starting to emerge, creating the impression of pitting throughout the image. The immediacy of the notes of the original source is tempered by the spectral envelope of the violin with a gradual onset of pitched notes that appear from the spectral remnants of the original source.
When coupled to a spatial movement, the rise and fall of the pitch material is suggestive of the sound moving toward and then passing the listener. This is much like the Doppler effect, a phenomenon that can be experienced when sound sources move toward the listener, with the compression of the oncoming wavefront resulting in a rise in pitch, and then continuing past the listener, resulting in a drop in pitch.

Another signal-processing technique used was granular synthesis. In general, granular synthesis breaks an audio signal into small fragments called ‘grains’. Theoretically, the grains can be as small as 1 millisecond in length and as large as several seconds. The individual grains can be treated like any other audio signal with variations to pitch, playback speed and volume in real-time. For more information on granular synthesis, I recommend reading Enda Bates ‘Composing, Perceiving and Developing Real-time Granulation in Surround Sound’. Nobuyasu Sakonda’s Granular2.5 is a series of MaxMSP patches that provide a means for modifying sound at the granular level. In sound example 2; granular choir, this sound is an example of vocal recordings processed using granular techniques. I use granulation sparingly, but it is an effective method for creating a sense of space within the sound by delaying the individual grains. Granulation can also be used to create dense sound textures through subtle shifts in the grain size, pitch and playback speed.

Sound example 2: Granular Choir
Composing layers

The layers in Pilate consist of a combined set of sounds that share the same temporal space so that they are perceived as a single unified body. Over the duration of the layer the individual sounds should begin to emerge, adding a sense of depth and richness to the sound. The layers were created using Audacity, to modify the intensities and timing of each sound, and then mixed down to create a single monophonic sound file. To assist with their creation, I often revisited the narrative, the journey for the listener and the type of mood I was aiming to create within each theme.

Heaven contains six layers. Each layer contains exactly the same sounds: An1x*Violin, modified wind and modified bells. In comparison, An1x*Violin, which I will refer to as the main voice, is the more complex voice in terms of the emergent pitch material within its structure, so it was important for me to present this sound with a high degree of clarity to the listener. Despite the complexity of the main voice, it lacked a bed of sound that I felt should carry the sound into the space. The bed of sound is introduced through the addition of the modified bells and wind. The wind is actually white noise passed through a series of band-pass filters, leaving only the high-frequency components. The bells are samples from a studio recording of small bells bought from a local craft shop. The samples have been independently pitch-shifted up an octave, and time-stretched in Audacity. Mixing this with the main voice creates a tension between the non-pitched material and the onset of the pitched material as sounds begin to break through one another.

Sound example 3: Celestial Body

In sound example 3, ‘Celestial Body’, non-pitched sound in the form of the modified wind, is heard first. Increasing in intensity it acts to mask the introduction of the modified bells, which is followed by the main voice. The masking effect is most discernible at the beginning and end of the layer. As the noise subsides the main voice breaks through into the space. The bells can be heard throughout the duration of the layer; however, intensity is reduced so that the sound always sits underneath the main voice.
To the ear, the difference in timbre between each layer is almost negligible. By applying subtle variation in the timing of sounds, their placement within the sequence and their intensity with which they begin to emerge, provides a context for distinguishing one layer from another. Yet, if the layers were to share the same spatial location and were played at exactly the same time, the impression would be that of a single stream. In order to separate the layers such that they are perceived as separate streams, it is important to separate them spatially but also to give each layer different spatial movements.

Spatial composition

My intention for Heaven was to draw the listener's attention to the layers moving in and around the listening space. Emphasis was placed on spatial location and movement while providing suitable listening conditions that made it possible to perceive the emerging structures from within the bodies themselves. To do this I limited the number of perceivable layers to only two at any one time, ensuring the density and complexity of the soundfield was kept to a minimum.

My aim with the spatial movements in Heaven was to surround the listener with the suggestion of celestial bodies. These sounds rotate slowly around the listener, gliding in and out of the listening space like distant comets. To give the sense of these bodies moving into the space and passing the listener, the sound was introduced with a non-pitched voice gradually increasing in intensity, pitch and spectral richness. At maximum intensity the sound has a distinct vocal character, as it passes the listener. The sound then exits the space, gradually dropping in intensity and pitch to a non-pitched sound. The technique attempts to accentuate the expansive nature of the heavens and a sense of distance between the listener and sound by playing with the clarity and masking of sounds within the environment using white noise. The movement of the sound is also heightened with gradual rise and fall in pitch over the duration of the sound event, which is suggestive of the Doppler effect.
For Earth I was interested in three types of spatial trajectories. The sounds used in this section are predominantly monophonic studio voice recordings and some environmental recordings. The first layer adopts a strategy where static sounds were positioned in various virtual locations around the listening space using ambisonic techniques. This layer consist of a number of whispers that were filtered such that the words were rendered incomprehensible to the listener, giving an impression of someone speaking within another space. The second strategy simply places static sounds at individual loudspeaker locations. The sounds used in this layer are clearly recognisable voice recordings. The distinct and abrupt presence of voices appearing at location of the loudspeakers, presents a moment of drama against the more distant sounding whispers. The last spatial trajectory used, is a continuation of the first section: the rapid movement of sounds around the listening space.

Bridging Earth and Mind is the sound of thunder as it cracks over the listener’s head, extending into the distance across the sky. Herein lies a problem for composing spatially any sound that requires a distinctly unique spatial movement as perceived in the natural environment. From my own experience of electrical storms, the sonic event does not project from one static location. After the drama of the initial percussive crack, the sound tends to ripple out across the sky with a rapid succession of smaller strikes, conveying to the listener an overwhelming sense of scale and distance. Each successive strike is distinct and spatially different but still perceived to be connected as the sound moves outward. I wanted to capture this experience and create the impression of large electrical storm with the sound rippling across the sky. The qualities I was looking for needed to contain the first distinct percussive strike and the appropriate sequence of smaller successive strikes to give a strong sense of a large interconnected system.

The sound used to reproduce the storm was extracted from a recording taken on a field trip to Croajingolong National Park in 2005. In the original recording, the initial percussive strike occurs directly overhead, beginning a sequence of smaller strikes as they roll away across the
sky and into the distance. By the end of the recording, the latter strikes have moved some
distance from the listener, are not as intense and begin to merge with the general rumbling
in the background. Listening to the recording more closely, I identified five parameters I
could use compositionally to achieve a reasonable spatial recreation of a thunderstorm:
spatial location, spatial displacement, onset time, timbre and intensity.

I approached the scenario by first testing a number of simple trajectories to establish the
displacement of the percussive sounds forming the effect of the rippling across the space. A
17-second monophonic sample extracted from the original recording was coupled to a spatial
point located directly above the listener. The playback of the sound was looped as I tested
movements by manually shifting it in one direction along the horizontal plane with variations
to the displacement of the sound: starting and ending locations, the direction of travel and
rate of movement. Figure 9 demonstrates one of the many variations, showing the starting
location above the listener and the spatial displacement across the horizontal plane, against
the waveform and spectrogram of the 17-second sample.

Sound example 4: Thunder

In Figure 9, the spectrogram of the thunder is overlaid with a spatial scheme to demonstrate
the movement of the sound over the duration of the sound. In the spectrogram, the colour
red represents peak intensities below 300Hz, while the vertical bands in blue represent the
complex succession of percussive strikes. The starting location of the sound source is
indicated by the circle at the beginning of the waveform, positioned directly above the
listener’s head. The path extending across the horizontal plane over the duration of the
sound file indicates spatial movement, and the vertical line represents the height of the
listener’s head at 1.3m.
From the results of the tests I decided that moving the sound was not appropriate for creating the impression of thunder moving across the sky. By shifting the location of the sound source around a virtual space, the resulting soundfield was also displaced. The shifting of the soundfield I perceived to be unnatural. While this technique may have been appropriate for spatially displacing the onset of discrete percussive events that over time do not overlap one another, the complex combination and intersection of percussive events with the continual modulation of low frequencies within the recording made it difficult to spatially separate one event from the next. I decided to test another approach by first placing a number of sounds at static locations around the listener and mirroring the spatial displacement of the sound sources across the virtual environment.

The resulting effect did not satisfy my original aim, which was the sense of rippling; however, it did achieve a greater sense of envelopment, due to the positioning of lateral sound sources around the listener. I was not too concerned about the accuracy of the locations as I was not after a completely symmetrical environment (as is demonstrated in Figure 10, which serves as a guide to the placement of sound sources around the listener).
With sound source locations all sharing the same sound file, a copy of the unmodified thunder extract, the perception of the thunderstorm, as it was spatially displaced across the listening space, retained a single homogeneous voice. In order to suggest variation across the dimensions of the reproduced soundfield, differences in the onset time were introduced between each of the sounds, with exception of sound source 0, by individually modifying their intensities, frequencies and onset time. The degree of modification made to each sound file was determined by ear when sounds where positioned within the virtual environment and compared against sound source 0.
Table 3 lists the sound source locations relative to the listener, and signal modifications made to each sound in the virtual environment.

Table 3: Sound source locations and modifications

<table>
<thead>
<tr>
<th>Sound source</th>
<th>Location on horizontal plane</th>
<th>Location on vertical plane</th>
<th>Intensity modification</th>
<th>EQ modification</th>
<th>Timing modification</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Centre</td>
<td>Top, directly above</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>1</td>
<td>Front-left</td>
<td>Mid, above</td>
<td>Subtle reduction</td>
<td>Subtle high roll-off</td>
<td>8-sec onset</td>
</tr>
<tr>
<td>2</td>
<td>Front-right</td>
<td>Mid, above</td>
<td>Subtle reduction</td>
<td>Subtle high roll-off</td>
<td>8-sec onset</td>
</tr>
<tr>
<td>3</td>
<td>Rear-right</td>
<td>Mid, above</td>
<td>Subtle reduction</td>
<td>Subtle high roll-off</td>
<td>8-sec onset</td>
</tr>
<tr>
<td>4</td>
<td>Rear-left</td>
<td>Mid, above</td>
<td>Subtle reduction</td>
<td>Subtle high roll-off</td>
<td>8-sec onset</td>
</tr>
<tr>
<td>5</td>
<td>Front-left</td>
<td>Low, head height</td>
<td>Heavy reduction</td>
<td>Heavy high - mid roll-off</td>
<td>12-sec onset</td>
</tr>
<tr>
<td>6</td>
<td>Front-right</td>
<td>Low, head height</td>
<td>Heavy reduction</td>
<td>Heavy high - mid roll-off</td>
<td>12-sec onset</td>
</tr>
<tr>
<td>7</td>
<td>Rear-right</td>
<td>Low, head height</td>
<td>Heavy reduction</td>
<td>Heavy high - mid roll-off</td>
<td>12-sec onset</td>
</tr>
<tr>
<td>8</td>
<td>Rear-left</td>
<td>Low, head height</td>
<td>Heavy reduction</td>
<td>Heavy high - mid roll-off</td>
<td>12-sec onset</td>
</tr>
</tbody>
</table>

As a copy of the original thunder extract was used for all sound sources, the intensity, frequency and timing of each sound, with the exception of sound source 0, was manually modified before coupling to the spatial point source. Figure 11 shows the waveform of the unmodified sound source 0 against its spectrogram.
Figure 11: Spectrogram of thunder

Figure 12 shows a comparison of sound sources (1, 2, 3, 4) located away from the listener, on the same horizontal plane positioned above the listener’s head. Each sound was reduced in intensity with subtle variation high-frequency roll-off. The onset time for each sound was set to around 8 seconds. The frequency scale is from 0Hz to 3700Hz.

Figure 12: Comparison of source intensities 1 to 4

Figure 13 shows sound sources (5, 6, 7, 8) that are located the furthest away from the listener but on the same horizontal plane positioned at the height of listener’s head. These sounds represent the low-frequency rumble of the thunder, with heavy equalisation to remove the high- to mid-range frequencies with an onset time of 12 seconds. The frequency scale is from 0Hz to 300Hz. Because this sound predominantly consisted of low-frequency rumbling, all four sound sources (5 to 8) use the same modified material.
The sequence for reconstructing the event is shown in Figure 14, with the time in seconds displayed across the top. Sound sources are indicated below the main timeline in parentheses. In this sequence, sound source 0 is first heard at a time of 0 seconds, followed by sound sources 1 to 4 with an onset time of 8 seconds, then the distant rumble fading in at a time of 12 seconds. The overall duration of the entire reconstructed event is over 32 seconds.

Sound example 5: Thunder-mid

Sound example 6: Thunder-low

Spatial rendering

Once all the layers were spatially composed, their trajectories and position in space were each individually encoded and then decoded, creating an eight-track multichannel file. The folder structure for each decoded layer is shown in Figure 15. The loudspeaker arrangement used for the ambisonic encoding and decoding process was based on an eight-loudspeaker
cubic arrangement, with each track mapped directly to a loudspeaker channel – track 1 equating to loudspeaker channel 1 and so on. Using Logic Audio Pro 7, the decoded layers were imported into a new project and the themes of Heaven, Earth and Mind were reconstructed. Once the process was complete, the entire project was bounced to a single eight-track file. This file was then used in performance as the master playback file.

Performance

Pilate was performed at BMW Edge, Federation Square, on 3 May 2006, as part of the SIAL Sound Studio’s SPECTROM02 electroacoustic concert series. In translating the work from the studio’s eight-channel cubic configuration to the performance space, I had to ensure eight of loudspeakers installed within the space matched the cubic configuration generated in the studio. The criteria for performing the work required a symmetrical playback environment in which the loudspeakers formed a cube around the audience. Loudspeakers also needed to be matched to ensure the differences in sound quality between individual loudspeakers was minimised and the perception of reproduced soundfield was stable, regardless of the listener’s location within the space.

For playback, the system consisted of eight Genelec 1032A loudspeakers placed within a cubic arrangement around the space. This eight-channel arrangement formed part of a larger
24-channel loudspeaker system installed within the space, as shown in Figure 16 and 17. Of the 24 loudspeakers installed in the space, only 8 were used for Pilate. The red circles highlight loudspeaker used and their relative locations. Audience seating is located within the loudspeaker configuration and forms a ring around the centre. Loudspeakers 1 to 4 were located on the floor and loudspeakers 5 to 8 were located on the balcony.

Figure 16: Two views of the 3D model of BMW Edge in orthographic view

Figure 17: 3D model of BMW Edge in top view
Summary

Pilate is the first work in which I used ambisonics as a compositional tool. My aim was to create a spatial listening environment that mirrored an experience of a real-world environment. Working through the process of making, I was learning the technique. This involved the placement of sound sources and the recording of spatial trajectories within a virtual three-dimensional space. I was learning how I could best use the tool within my studio workflow. This involved the process of ambisonic encoding and decoding to create the eight-channel render. At the same time I was also learning about the tool’s constraints and what I could and could not achieve by using it – for example, what effect distance had on the perception of sound within the reconstructed environment, or how fast or slow could a sound be moved within the space. The learning process progressed through small studies, in which I tested and retested scenarios to understand which techniques worked best.

Reflecting on this work, I encountered a number of spatial and spectral problems that, at the time, I was unable to completely resolve. This was demonstrated in my attempt to create the effect of thunder rippling across the space. I first sensed a problem when I was attempting to move the sound across the virtual ambisonic environment. With the entire soundfield shifting, I sensed this spatial transformation to be unnatural. I now see why my tests failed. To sense the situation as ‘unnatural’ was an important clue for unlocking the acoustic qualities I associated with the term ‘natural’. By questioning my interpretation, I drew a pathway from the material, back to how I framed the work. Had I been more acutely aware, then, the ongoing process of reflection should have guided me as I progressed through the process of ‘making’. In this context, the problem was not a singular issue but a combination of issues that included spectral separation and spatial displacement. Each issue need to be addressed with different techniques.

In the context of spectral separation, the sound I used in my piece was an extract taken from an outdoor recording. Because the technique used to record the thunder did not discriminate against any other sound within the environment, it captured the entire spectrum of sounds
within that space. By applying tight filters to the original sound material, the higher frequency components, required for the rippling effect, needed to be separated from the body of other sounds. Once separated, the higher frequency material could be enhanced to draw out the more percussive elements of the sound material. In the context of spatial displacement, it was important to match the type of sound against a spatial trajectory that made sense acoustically. Applying a simple linear trajectory to the thunder sound did not match natural-world situations. Instead a trajectory that shifted in time and space, matching the percussive sounds of the thunder, may have offered better results. Even though I was able to find a compromise, many of the problems I encountered could have been solved had I been more aware of the materials and the techniques I used during the process of making.
Metamorphosis42: A Heterogeneous Approach

Background

In August 2008 I was invited by Martin Renaud to present a new multichannel work for P.U.L.S.E (Performing the Urban Landscape), a multimedia project funded by Arts Victoria and the City of Melbourne. It was made up of a series of monthly sound, dance, video and theatre performances. In 2009 the program ran over a period of four months, with one performance per month, each focusing on a specific discipline. The proposed site was a rooftop situated within the heart of the urban environment. This was a unique opportunity to design, compose and realise a multichannel work exploring an open space situated above street level. The work was presented as a two-channel composition, manually diffused over an eight-channel loudspeaker system. The following artistic statement positions the work as an exploration of the notion of the heterogeneous space:

Metamorphosis42 is a response to the notion of the heterogeneous space, expressed through an electroacoustic work performed within the urban environment. The work is open to variation and this forms an essential performance component for its realisation within the environment. Metamorphosis42 is a work for two performers with electronic music over eight loudspeakers with live audio manipulation.

*Metamorphosis42* is a two-channel piece that explores an approach to designing for a complex sound environment. This work draws from two sources for inspiration: the description of the metamorphosis effect as captured by Cresson and Paul Zucker’s (Arnheim, 1978) visual interpretation of a heterogeneous space. Cresson describes the metamorphosis effect as a perceivable change in the sonic environment that is characterised by a temporal instability in the relations that link the components of an entire system (Augoyard, 2006). This instability gives the listener the impression the system is continually shifting.

According to Cresson, the metamorphosis effect is often experienced when the listener is
unable to distinguish individual sonic events from a rapid succession of other sonic events, due to persistent fluctuations in sound criteria: timbre, pitch, intensity and location. Highly reverberant spaces also support the metamorphosis effect. Reflected sounds propagate throughout space, giving the impression of multiple sound images reaching our ears. The metamorphosis effect is best heard from elevated spaces such as rooftops. In elevated spaces, the surrounding environment softens individual sound events and with distance the higher frequencies are tempered through absorption in the air, creating a sonic ambiance as sound traverses upwards. The scenarios that support the metamorphosis effect generally occur when there is a superimposition of multiple sound sources heard simultaneously over time, such that the ear perceives a totality of sound. The suggestion is that as the variations in sound intensity, timbre, pitch of individual events move in time, they also move in and out of the listeners perception, from foreground to background, such that the sounds that begin to appear in the background assist with the perceived changes to the totality of the entire environment.

Zucker’s interpretation of the heterogeneous space describes a perceivable change in the arrangement of objects characterised by instability in the spatial relations existing between objects within an entire system. A heterogeneous environment is often experienced in scenarios where there is a high degree of variation in the perceived proportions of physical objects contained within the space. This variation creates discontinuity within the environment, creating a sense of confusion for the viewer. This idea is useful for shifting the listeners’ perception of sound, by playing with the temporal and spatial proportions of the sounds. Cresson uses the term ‘anticipation’ to describe the phenomenon of hearing a sound without the sound reaching our ears (Augoyard, 2006). The expectation that a sound event will occur, results in the listener pre-hearing that particular sound. Applying this effect in sound design, serves to decouple the listener’s expectation from the actual auditory experience.

Two rooftop sites were scoped for this project. The first site, located above City Village, 225
Bourke Street, in Melbourne’s Central Business District, informed many of my early design ideas. Unfortunately, City of Melbourne restricted access to this site midway through the P.U.L.S.E program. With this change, my design for that space was abandoned. Despite this, I discuss the work leading up to the performance to demonstrate how my framing of my work shifted from an experience of both sites. The second rooftop site is a private residence rooftop in Northcote. This is where the work was finally presented to a public audience.

The City Village rooftop is located nine floors above street level. The space measures approximately 20m long by 10m wide and is accessible via a lift, with a foyer at the southern end of the space. At the northern end of the space, there is a series of air-conditioning ducts and pipe works used to service the building. On both the eastern and western sides of the space, tall city buildings enclose the space. Before visiting the site, I imagined the space would be overwhelmed by the incessant sounds of the city. My expectation was that I would hear loud, busy and chaotic street activity, mixed and shaped by the echoes and reflections from the surrounding buildings.

On the day of the site inspection, I was surprised to find that my experience of the sounds on street level did not translate nine floors above. This was certainly a ‘wow’ moment when first stepping out onto the rooftop. I can only describe my experience as strangely tranquil. The
sounds of horns, sirens and trams melted into one coherent texture, softened by the envelope of the physical landscape.

After the site inspection I decided to present the work as a multichannel piece over an eight-channel loudspeaker system. The hire of equipment would not be confirmed until two to three weeks prior to the performance and this uncertainty had the potential to significantly impact design decisions that were contingent on having eight loudspeakers. By establishing a line of communication with the production manager, my technical and artistic requirements of the work were communicated early. The necessary documentation, detailing hardware requirements, proposed lighting and spatial designs for audience seating and loudspeaker locations, were available for immediate reference. The three-dimensional model with loudspeaker and mixing desk locations and the two-dimensional technical diagram, with the addition of performer locations cable runs and lighting requirements, is shown in Figure 19.

![Figure 19: 3D model of City Village rooftop](image)

In late 2008, with a change in council, a review of public art projects deemed the use of the City Village rooftop space a risk to public safety. Access to the space was denied and the entire performance program was postponed by six months. By mid-2009 a new rooftop venue was confirmed, above a privately owned residence located on the corner of High and Westgarth Streets in Northcote, Melbourne.
Much to my disappointment, the size of the site was approximately half the size of the City Village rooftop and only one floor above street level, as shown in Figure 20. With this in mind, a new loudspeaker configuration was devised. The three-dimensional model showing this configuration is shown in Figure 21. In an effort to minimise any further impact on my work, I decided on the most flexible playback configuration: a two-channel stereo environment. The decision to move from eight channels to two, postponed compositional activities relating to sound spatialisation until a later time. If loudspeaker hardware proved to be a limitation, my work could still be presented over a reduced loudspeaker arrangement, with a minimum requirement of two.

A 3D model of the Northcote rooftop is shown in Figure 21 and a photo from the eastern side of the rooftop is shown in Figure 22. The Northcote rooftop is oddly shaped, with an old shed jutting out into the side of the space it obstructed both sound and visual sightlines from the position of the mixing desk. This made it difficult for me to engage with the entire performance space using a full complement of loudspeakers. To address this concern, the eight loudspeakers were arranged into two quadraphonic systems. The idea was that I could address all eight as one whole system, or two separate quad systems.
Figure 21: 3D model of Northcote rooftop with quad loudspeaker configurations.

Figure 23 shows part of the loudspeaker configuration prior to rehearsals. Due to the confined nature of the space and the intrusion of the tripod stands into the space, two loudspeakers were removed from their stands and placed directly on the floor. This configuration remained for the duration of the rehearsals and performance.

Figure 22: RCF loudspeakers installed

Figure 24, a stitch of two photos, shows the view over the edge of the rooftop. From left to right, the first image is a view looking east, towards the intersection, and the second image is a view looking west at the traffic along Westgarth Road.
Metamorphosis42 was a response to the City Village rooftop sound environment. My perception of the space as acoustically homogenous, framed my approach. By using ambisonic techniques – my aim was to create a musical experience that mirrored the perceptual qualities of the site. Reflecting on this, I realised I was confronted with a potential problem: by placing the listener within a homogeneous field of the music, could this move neglect the surrounding environment? If the site was to be a considered part of my musical response, then my approach needed to create space within the music I composed, for the natural environment to exist. Arriving at this conclusion, I felt my original approach could potentially detach the listener from an experience of the site altogether.

Collaboration

In November 2008 I invited Karl Willebrant, an accomplished musician, to collaborate on the project. My decision to work with Karl could easily have worked against the project based on our differences in musical taste. However, I was confident that any such tension could be resolved through the collaborative process and despite our differences in musical sensibilities, our passion for creating and improvising with sound was an important quality that I felt could
be used to explore the concept of the heterogeneous space. We decided to meet at least once a fortnight to discuss ideas and how we envisioned using the performance space. We discussed musical instrumentation, including how it could be used, in what capacity and what it could offer musically; we also discussed loudspeaker configurations, mixing desk operation for sound projection and the use of digital effects pedals. We also spoke about the composition of the work, what sounds were being used, what was created live and how sounds were to be reproduced in the space. These conversations were important for communicating our ideas, but they also focused on the design of the work and ways we could bring together our individual artistic contributions.

Composition

For the two-channel electronic music, I imagined fragments of sound projected into the performance space, colliding with the sounds from the surrounding environment. Using real-time signal-processing techniques my aim was to create a new sense of space, which over time, transformed against the natural sounds of the environment. A variety of sounds were collected, sampled and recycled from previous projects, going back to 2002. These materials were pooled into the five categories, as shown in Figure 24: voice, instrument, environmental, mechanical and noise.

![Folder structure](image)

**Figure 24: Folder structure**
The sound materials included studio voice-over recordings; musical instrument and synthesiser samples; and electronic and mechanical sounds. There were also a number of field recordings collected around Melbourne and a variety of noise-generated sounds. I used sounds as I found them, with very little time spent in the studio editing or cleaning sounds. Maintaining a two-channel format throughout the process of making meant the file size was small and easy to manage. All sound work was performed on a Macintosh G4 Powerbook laptop using MaxMSP and Logic Pro 7. Working this way meant I could easily move between spaces, requiring only a stereo system or headphones to listen to the work.

I started with small two-channel prototypes, which were formed by randomly combining individual sounds into small mutually distinct groups. What I enjoyed most about this approach was that it ensured the process of selecting sounds was not prejudiced by my own musical aesthetic. By using this approach, individual sounds within each category had equal opportunity to be included within the work. With sounds placed into each of the five categories, a value was given to each category. In addition to the sound categories, five different types of effects were used. Effects included granulation, pitch shift, data gate, spectral transformation, and reverberation. Any of these effects could be applied to selected sound groups at any stage in the process.

Table 4 lists sound categories and effect types against their respective selection values. Random selection is ranked between 0 and 5, with a 0 value equating to ‘no sound’ and ‘no effect’. A sound having ‘no effect’ against it was considered a worthwhile value, while ‘no sound’ having an active effect was not. A zero value against a sound reduces the number of sounds within a combined sequence by one, and active effects against that sound are ignored.
Table 4: Sound categories and effect types

<table>
<thead>
<tr>
<th>Sound type</th>
<th>Effect</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>No sound</td>
<td>No effect</td>
<td>0</td>
</tr>
<tr>
<td>Voice</td>
<td>Granulation</td>
<td>1</td>
</tr>
<tr>
<td>Instrument</td>
<td>Pitch shift</td>
<td>2</td>
</tr>
<tr>
<td>Environmental</td>
<td>Date gate</td>
<td>3</td>
</tr>
<tr>
<td>Mechanical</td>
<td>Spectral transform</td>
<td>4</td>
</tr>
<tr>
<td>Noise</td>
<td>Reverberation</td>
<td>5</td>
</tr>
</tbody>
</table>

With sounds placed into each of the five categories, a patch created in MaxMSP was used to randomly generate a combination matrix. Each row in the combination matrix consisted of 11 values. The first value in the matrix is the row index. The five values following the index relate to sound category selection. The remaining five values relate to sound effect selection. Output values from a 10-step, randomly generated sequence is shown in Figure 25. For Group 1; at index 0, the five values in the sequence (2, 2, 2, 4, 0) represent the combined set of four sounds from two different categories, three of which belong to the instrument category and one to the mechanical category. The next five values (2, 3, 1, 2, 3) in the sequence indicate the type of effect used on each sound. The final effect value of '3' is disregarded since there is a 'no sound' value against the fifth position.

```
0, 2 2 2 4 0 2 3 1 2 3;
1, 1 1 5 0 3 0 5 5 0 2;
2, 0 0 2 5 5 2 0 3 0;
3, 0 2 5 4 0 0 4 5 0;
4, 4 5 4 3 2 5 4 3 1 0;
5, 4 2 5 1 0 1 1 3 5 0;
6, 0 0 3 1 1 0 4 4 2 2;
7, 2 2 5 3 1 3 4 5 4 5;
8, 1 2 0 0 5 3 2 0 5 1;
9, 2 5 3 2 3 2 0 3 0;
10, 5 4 3 4 3 1 5 5 1 4;
```

Figure 25: Combination matrix
Once the sequence for each group was formed, a second random selection process was used to select one sound from each of the designated categories. The sounds selected through this process were then imported into a single playback buffer, creating the sequence. As each sound group was played through, the playback speed and direction was randomised. From this process, sound groups were captured in real-time into a second buffer. The final stage involved a small patch created in MaxMSP to split the sound groups into small fragments. This final process was not applied to all sound groups. Figure 26 shows the result of the fragmentation process, using the gating patch in MaxMSP. The waveform is visualised using Audacity.

![Figure 26: Fragments of recorded voice samples](image)

Three different sound examples of the prototypes are presented on the accompanying CD. Prototype 1 is a collection of noise, instrument and environmental samples, against spectral pitch transposition and granulation. Prototype 2 is voice, instrument and environmental samples against spectral pitch transposition, and Prototype 3 is voice and instrument with heavy use of the gating effect.

Sound example 7: Prototype 1.

Sound example 8: Prototype 2.

Sound example 9: Prototype 3.

The process of fragmenting sound groups was performed using a data gate patch created in MaxMSP. When activated, the patch processed a single audio signal by splitting the group
across two channels. The patch used for the fragmentation process is shown in Figure 27. From the patch, a random number generator was used for alternating the on/off ramp for each audio channel and a pulse generator was used for activating and synchronising the gate and ramp values against the incoming audio. A great deal of time was spent ‘tuning’ the software in order to get the fragments as small as possible without introducing digital clicks within the final recording. This was achieved by varying the ramp on/off values against the pulse generator value. Once the processing was complete the final work was prepared in Logic Audio Pro 7.

![Diagram](image.png)

Figure 27: MaxMSP Data gate patch

The instruments used for the work included bass guitar, guitar effects pedals and laptop. All instrument audio signals were sent directly into the mixing desk inputs. The first eight mixing desk input channels received audio sent from the laptop. The laptop was used for the playback of the pre-composed two-channel piece and the matrix mixing of audio signals within MaxMSP.

The software matrix mixer used in performance presented a method for dynamically remapping incoming audio signals to output channels via the MOTU896. The MOTU896 is a multichannel interface that makes the connection between virtual software channels within the laptop and the mixing console, located within the space. By changing the signal mapping in the software, it was possible to move quickly between a configuration that addressed all eight loudspeakers, as a complete system, or two smaller quad systems that mirrored each
other, or two entirely independent systems. Quad-1 consisted of loudspeaker channels 1 to 4, and Quad-2 consisted of loudspeaker channels 5 to 8. At any time during playback, by key press, I could dynamically remap input signals into the matrix mixer to any physical loudspeaker location.

The three snapshots of the audio matrix settings in Figure 28 show where input signals into the matrix were mapped to loudspeakers during the performance. Audio signal input into the software matrix is across the top and audio signal outputs, labeled out1 to out8, on the right-hand side of the matrix.

Matrix A was used at the beginning of the piece and alternating between settings B and C during the performance. For A, the left input channel of the two-channel electronic music was sent to Quad 1 output channel 1 and the right input channel was sent to output channel 2. The monophonic signal received from the electric bass was mapped to Quad 2, outputs 5 and 8 respectively. This configuration treated the listening space as two distinctly different sounding areas.

The mixing desk used for the performance was an Allen and Heath 24-channel analogue-mixing console. The mixing console was used to control the loudness of all audio input signals feeding back into the processing chain and for controlling signal level before spatially diffusing the material to loudspeakers into the space. Following on from the eight MOTU896
inputs into the mixing desk, a single monophonic input signal from bass guitar and a monophonic input signal from the effects pedals was inserted into input channels 9 and 10. From the mixing desk, instrument signals were mixed and then broadcast to loudspeakers.

The signal-processing chain included the software audio matrix mixer, managed using a laptop, and external effects pedals, controlled by Karl. By utilising the mixing desk’s two auxiliary outputs it was possible to send any mono instrument input signal either to the external effects pedals or back into the laptop for remapping. By adjusting the level of signal feeding to either AUX1 or AUX2, I could decide when, and to what degree, signals could be treated using the laptop matrix mixer on AUX1 or effects pedals on AUX2. By treating all input signals in this manner, then the process of mixing both the dry and processed audio signal, created a temporal and spatial juxtaposition within the listening space.

Performance
The performance lasted approximately 25 minutes and was run over two nights. As the work was improvised, both performances were very different in terms of Karl’s use of the pedal effects. The first section opened with a series of pitched sounds using the bass guitar and projected into the space using the bass bin. This then led to the introduction of the tape piece, which consisted of slowly rising pitched sounds, both synthesised electronic sounds and sampled voice. Starting from two loudspeakers, sounds were projected quite softly into the space, slowly increasing in volume to include the remaining six loudspeakers surrounding the audience, drawing focus away from the sounds of the street. The volume at each loudspeaker was modulated slightly to give the effect of sound layers moving slowly around the space.

The first section reached a crescendo before moving into the second section. The second section consists of short, broken sound segments, again playing with pauses and allowing sounds from the street to re-enter the space. The volume at each loudspeaker was
modulated using short, quick gestures, giving the impression of sounds randomly appearing around the space. The third and final section consisted of short, broken sound segments playing at a much faster rate. By modulating the distribution of sound across all loudspeakers presented a complex structure that slowly shifted around before completely enveloping the entire space.

Summary

Despite the complications with the shift in performance space, my work progressed without further impediments. In hindsight, my original design intention could have been problematic even in the original space. Had I not reflected on my approach to spatially compose the sound, my musical interpretation may have had an undesirable affect by neglecting an experience of the site altogether. My reframing of the work was a necessary process, before any compositional work started. My decision to produce the music using a two-channel format, instead of a multichannel format, reduced my dependency on specific equipment in the studio, but also in performance to reproduce the music. This decision also meant that I didn’t need to consider rendering a full spatial mix and by doing so, I avoided the common problem of trying to accommodate a fixed loudspeaker configuration as well as trying to ensure there was enough space for the audience, all within a confined space. Instead, I could focus my time and efforts towards composing the music and the collaborative process for realising the work.
Conclusion

This exegesis is an account of two spatial sound projects created and realised between 2006 and 2009. In this exegesis I have described the process of ‘making’ and the concepts and techniques I have used to realise each project. Located within the context of design, my research explores two modes for spatial sound composition, which at its heart contemplates the potential for the phenomenon of the sound experience to guide the design of sound and its reproduction using electroacoustic techniques. My research inquiry is based on the premise that the process for designing sound can be framed using the ‘homogeneous’ and ‘heterogeneous’ terms. I apply these terms in my research, to embody the essence of a compositional methodology, explored through an analysis of my projects and by engaging with a process of reflection and listening. This exegesis is an account of that inquiry and the knowledge I have gained through a process of reflection. In this closing section I present my findings to each of my research questions;

Question 1. How can the notions of the homogeneous and heterogeneous be used to frame the process for designing spatial sound?

Initially driven by an interest in the sound design process as a way to create spatial music, my research shifted to the experience of sound and its relation to space, physical and imagined. By engaging with my projects through a process of listening, I became aware of the perceptual differences between the two works. This process enabled me to construct the ‘homogeneous’ and ‘heterogeneous’ categories, which I first used to describe a spatial quality of my work based on a listening experience. What intrigued me most about this process was; how these two terms emerged from a listening experience to then form the central ideas that enabled me to draw a distinction between my projects. This led me to undertake an examination of my compositional approach to better understand how I have applied sound production and reproduction techniques to create a sense of space in my work and how the ‘homogeneous’ and ‘heterogeneous’ can be used to frame ways of working with sound and
In my projects, Metamorphosis42 and Pilate, I demonstrated two approaches to the composition of spatial sound. Both approaches use similar sound production tools and sound reproduction technologies to realise the music, however, an important distinction in approach between Pilate and Metamorphosis42 is how spatial production and reproduction techniques can be applied during the compositional process; to modify and organise the perceptual characteristics of sound within the music. From a conceptual perspective, the ‘homogeneous’ and ‘heterogeneous’ terms can be used to frame a musical work, where emphasis is placed on the perceptual characteristics of sound as a considered component of the spatial listening experience. The ‘homogeneous’ and ‘heterogeneous’ characteristics of the spatial listening experience then can be used to guide the creative processes to construct or deconstruct an impression of space that is then conveyed to the listener through sound, as a spatial sound experience.

By acknowledging the physicality of the sound experience, my research proposes that the notion of the ‘homogeneous’ builds on the physical relations of sound and space. If our experience of sound in a real-world scenario is considered coherent, then, by applying the notion of the ‘homogeneous’ experience to a compositional process in sound design, the approach seeks to faithfully reproduce the perceptually coherent sounding qualities we experience in a real-world scenario. This approach is predicated on the fact that the sensations of sound are the result of vibrating materials and the physical qualities of these materials – their shape and density, for example, directly influence how sound is perceived. As a sound pressure wave moves through the atmosphere, it is reflected and diffracted off the many surfaces it comes into contact with. The sound reaching our ears is a complex combination of both direct and reflected waves that are each different in time, intensity and colour.
The notion of the ‘heterogeneous’, builds on the complex and dynamic relations of sound and space. This approach emphasises the interchangeable qualities of space and the potential for our imagination to associate the qualities of one sound with that of another sound. In the context of the sound design process, a characteristic of this approach is that sound is used as an affective device to explore, through a poetic re-imagination, an interior space in which sound is decoupled from its physical source. I use the term ‘re-imagination’ to emphasise the listener is not passive, but an active body engaged in this contemplation of sound and space. On this basis, the heterogeneous is not one singular homogeneous image bound entirely by the physical nature of the source. Instead, it is an affective experience that is bound to our senses and our emotions, reaching our ears through a patchwork of sounds that collide in space and time creating a transformation that occurs at the boundaries of perception.

In acknowledging the perceptual characteristics of the ‘homogeneous’ and ‘heterogeneous’ experience of sound and space, then by applying a compositional approach that combines multichannel reproduction systems with audio signal processing and spatial mixing techniques, it is possible to reconstruct a sound space that embodies ‘homogeneous’ qualities, in much the same way these techniques can be applied to deconstruct space, where the reproduced sound space embodies ‘heterogeneous’ qualities.

Even though the activities for composing and then realising a spatial musical work are separated in time by the very nature of the creative process, these activities adopt similar tools and techniques. These represent the enabling technologies I use to apply my spatial and temporal ideas to sound through the process of making. The creative process is a series of interconnected moves that I apply while making, to better understand both the materials and the tools and techniques. For Pilate, I demonstrated a compositional approach using the ambisonic technique to convey, to the listener, the impression of being situated within a true homogeneous soundfield. By emphasising the perceptually homogeneous characteristics of sound through the process of sound composition, the surround sound sensation became a central feature of the work and the ambisonic technique enabled me to express a
homogeneous experience of sound through my music. Even though the notion of the ‘homogeneous’ emerged after completing Pilate, my approach to the spatial organisation of sounds reflected my view of the physical world.

In my second work, Metamorphosis42, I demonstrated a compositional approach that started from an experience of the acoustic conditions of the City Village rooftop site. From this experience, my impression of the acoustic space was of sounds merging into a single coherent voice. From this experience, my intention to create a work using techniques that would enable me to reconstruct the qualities I perceived within the space. Continuing with this approach I identified a potential problem. The problem was not created from the process of making; instead, it was drawn into view from past experiences and methods used in Pilate to create the ‘homogeneous’ listening experience. Working through the problem demonstrated an applied knowledge that I used to reframe my approach to the composition of the work.

In the process of reframing, the notion of the ‘heterogeneous’ emerged. My approach was then an attempt to juxtapose the qualities of the rooftop environment against the music and create moments where the two could be perceived to work together. I decided against using ambisonics in preference to sound-diffusion techniques. I also explored methods for coupling a palette of sounds to create a suggestion of space rather than my original intention, which was to convey a coherent experience of sound in space. The new site was situated on the corner of a major intersection, and the direct sound from the surrounding environment filled the space. The constant traffic and pedestrian noise was intrusive, loud and unsettling. My experience of this acoustic space created an immediate tension. I feared my original concept for the music was no longer a response to the site. Despite the change in site, the electronic music already composed was not going to change. Instead, my response to the site was through the translation of the work, during performance, rather than through the electronic music. This meant I could still meet the curatorial objective, which was for the work to be site specific.
Question 2: What compositional techniques can be used to emphasise homogeneous and heterogeneous qualities?

For Pilate, I learnt how the notion of the ‘auditory stream’ could be applied using sound editing and processing techniques to modify a sound’s morphology using key perceptual characteristics, to group sounds into a perceptually ‘homogeneous’ structure. For Metamorphosis42, I learnt how I could reverse this process to emphasise the structural differences between sounds, to create sound groups that were perceptually ‘heterogeneous’.

The plan to construct a coherent listening experience shifted to an exploration of dynamic and complex relations, bringing the street-level experience up to the rooftop. By understanding the principles used in Pilate to construct a coherent listening experience, the same principles were applied, but instead to segregate the materials of sound. My point here is that by reducing the differences in perceived sound qualities, emphasis was placed on creating differences – where the differences make the space for change. This process extended to the realisation of the work using real-time signal processing and sound-diffusion techniques to continue temporal and spatial interference through stages of metamorphosis as it emerged into the physical space.

Reflecting on my research, I now have a better understanding of the techniques I can apply during the process of ‘making’ to acquire knowledge about the problems I encounter and the ways I can apply this knowledge to reframe my approach and address the problem. For Pilate, one of the problems that emerged was located in my attempts to convey an impression of thunder rippling across the space. By applying a spatial movement to the sound of thunder, I sensed that some aspect of the process created a result that I perceived as unnatural. My use of the term ‘unnatural’ is used to contrast my own personal experience within a real-world scenario. After an analysis of Pilate, I realised that in order for me to create such an effect, I needed a deeper understanding of the sound materials through their structural characteristics. By applying spectral analysis techniques combined with traditional...
editing techniques, the process of making should have led me to identify the perceptual qualities I needed to modify to convey a sense of realism to the listener. Instead my approach for resolving the problem progressed through a series of small explorations, which, in referencing Donald Schön, I describe as a ‘listening-doing-listening’ activity. From this activity, the resulting output of each move was compared against my experience of the naturally occurring event. Unfortunately, my lack of awareness at the level of the material meant I was unable to create the rippling sensation in the way that I had envisaged. I now have a better understanding of the ways in which I can work with sound, but also how to address and solve problem situations by acknowledging the importance of the sensory experience for attaining knowledge about the problem and appropriate techniques to solve it.

**Shift in practice**

Reflecting on my research, I have become aware of the journey I have taken to reach this point. This journey has challenged many of my preconceptions about the process for designing sound. I believe the act of designing is a journey. This journey is a lived experience and it is as much an exploration as it is a process for working. An outcome of this journey is the experience I gained through the process of making. It is from this process of making that the artifact is created. The artifact I create is my interpretation of the things I sense in the world, which I express through the medium of sound.

Prior to starting my research, I considered the act of designing to be a natural extension of my sound-design practice. An organic free-flowing process that was embedded and intertwined with so many other things I just did. I now see my sound-design practice as located between the built environment and the spatial music discipline, between the physical and the imagined space. Bridging the physical and imagined is a subjective experience of sound and space, and this represents a conceptual pathway that has enabled me to connect the sound sensation with the physical and imagined worlds. This connection brings meaning to the phenomena that I sense through perception and observation – the sensations of sound.
that I experience every day. The music I create is bound to my experience within the world and through my music, I express my interpretation of my experiences. I project this into the world, supported by an electroacoustic framework that is connected with the physicality of the built environment.

**Future work**

My research has only just touched the surface of four significant disciplines that have influenced my work: design, phenomenology, acoustics and spatial music. A complete historical account of each discipline is beyond the scope of this exegesis. However, this first step is significant in enabling me to continue to develop my practice with the knowledge, tools and techniques that I have acquired. I have established a process and an approach to designing that I can apply to my own personal sound designs. Elements of my research are already applied in SIAL’s postgraduate teaching program through the SIAL Sound Studio’s ‘Spatial Sound and Ambisonic Modelling’ elective. Future work in this area may be to explore the design of three urban spaces and, using the homogeneous and heterogeneous as models for creating the spatial sound environment, to explore methods for interpolating between the two. An outcome of this exploration may lead to the development of a tool for interacting between modelled spaces but to also a new interpretation of space that offers insight into the design of hybrid spaces.
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