Immersivity in Music Performance

with Original Compositions

THESIS

By

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ABSTRACT

The aim of this study is to critically investigate immersivity in music performance. It will evaluate how the combination of the performance space, musical material and delivery methods can produce unique and valuable sonic experiences to an audience. This investigative process hopes to highlight what compositional and spatial characteristics define this performance paradigm, with the goal to provide a taxonomy of key characteristics which creators must consider when devising an immersive music performance.

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1.Introduction

1.1 - Research Aim

The key aim of this study is to critically investigate immersivity in music performance and how it can be successfully implemented in practice. This investigative process hopes to better understand and explain what compositional and spatial characteristics define this performance paradigm. The key goal is to classify the specific characteristics composers and creators should consider when creating music for immersive performance. A literature review ascertains what components have been previously substantiated to be effective in this field, while contextualisation of this performance arena will provide theories to be further examined, whilst identifying any gaps in knowledge and practice. Primary research in the form of original works investigate how a variety of compositional and performance characteristics can contribute to immersivity, whilst assessing how these parameters can be utilised successfully. Performances of the original works enable critical evaluation of how the combination of the performance space, musical style and delivery methods can produce unique and valuable sonic experiences for the audience. Outcomes from the primary research also serve to inform the literature review by corroborating, contradicting and highlighting areas in need of further investigation. A key outcomes of this research process is the development of a definition of immersivity in music performance through a taxonomy of characteristics.

1.2 - Background & Motivation

It was evident from the outset that 'immersive music' as a performance paradigm lacked a clear definition. Typically, musical styles and practices adhere to some production and performative conditions. From writing traditional folk music to film scores, there are certain musical elements composers are aware of and audiences may come to expect. Spatial music for example, contains spatialisation techniques, a key characteristic of the style. Immersive music however, appears vague and limited in characterisation. Consequently, the scope of this research not only included the exploration of techniques for the development of

immersive music practice, but also an attempt to define this performance medium with some clarity, including characteristics that can be useable in practice. The research outcomes were therefore designed to present a practical methodology for immersive music practitioners in the development of innovative performance projects, with the additional aim to enthuse and engage audiences.

The author's background stems from a tradition in music composition, in particular popular and contemporary styles. The two decades of industry experience prior to the commencement of this study included the composition of various song-format records, production music and commissions. These projects were realised through various means, including record labels, music publishers and the DIY route (self-published and independently released). It is the sum of these experiences that gave the author the confidence to approach this research field; first, due to a proficiency in compositional practice, and secondly, due to the breadth of skills developed in creating and delivering big projects.

During this period, I developed a growing interest in immersive music practice. This was partly influenced by the already well-established field of immersive theatre, which had successfully developed a performance medium that deviated from traditional formats. The creative use of spaces and the potential for narrative variations depending on the audience's location, demonstrated that story telling did not need to be linear and the space itself can become part of the story.

Developments in gaming had also begun to establish immersive audio for AR and VR, in particular for the use with headphones, demonstrating a growing appreciation of the field within industry, and therefore the potential for immersive audio to emerge as a consumer standard. However, the idea of immersive music performance was limited beyond academic practice, with just a handful of established artists attempting to entertain audiences beyond the traditional front-back model. Although the technology has been available, the possible costs and implementation potentially outweighed the sectors enthusiasm. Yet the word 'immersive' had become fashionable across the creative arts, in many cases applied in an ad-hock manner (from the author's experience) to describe an event without clear application of immersive features. However, there were some grass-roots projects demonstrating

potential where immersivity was not explicitly implied but naturally occurring, which I experienced directly and was thus influenced by.

Sofar Sounds was one such example; a London based start-up which owes its success to an attempt in reinventing the magic of live performance. Secret shows were predominantly curated for small intimate spaces, which could range from an individual's front room to a place of work, art studio or brewery to name a few. In most cases, no loudspeaker system was employed, or a formal seating plan, with sometimes unusual delivery formats. Yet, the shows would create a wonderfully inclusive and attentive environment, perfect for both the performers and audience. For the author, this demonstrated that there was scope to explore this model further, by questioning why this model was perceived so well by audiences - was it due to the informal environment, the proximity to the performers, the use of space etc?

Artists such as Snarky Puppy began recording their albums in the studio with a live audience, all on headphones to preserve the recording quality, with the aim to capture the magic of a live performance, but on record. The audience were placed all around the musicians, rather than in a traditional performance space to directly influence the musician's delivery. The inclusive environment created a unique experience for the fans, knowing that they were present during the recording of the album. This again raised questions regarding the use of the space and the heightened relationship between the musicians and audience due to proximity. Blogotheque (an online music channel) is another example. The producers would surprise unknowing fans by placing them in unusual but unique performance spaces with their favourite artists – always in an intimate environment with an interesting use of space and delivery format. These are just a few influential examples which ignited and enthusiasm to explore space as a performance medium, with particular importance placed on creating an immersive music environment. My motivation to undertake this study stems from a passion for music composition and a continuing search to explore new and unique creative approaches, steering towards an exploration of immersivity in music performance.

The initial idea for this research inquiry was to simply experiment with immersivity as a performance medium and hypothesise on its potential. This soon navigated towards a necessity to explain what this medium actually means for the compositional practices

employed in this study and for others who wish to explore this field further. This is the key gap in knowledge established early on, which required primary and secondary research for delineation, and lies at the centre of this critical investigation.

As many of the influential factors described above entailed an audience-centred approach, this notion of perception and engagement remained integral to this study, which is reflected in the use of participants as primary research. Although the use of participants in music practice research has recently become more common, much of the language and the theories surrounding this field, with particular reference to live performance, lacked data on audience perception. Similarly, the compositional works had been highly experimental, absent of the audience-centred approach mentioned. The gaps in knowledge and research cited have served as additional motivators for the author, and their significance is further addressed within this study.

1.3 - Overview

Section A (chapters 2 to 6) provides a literature review which contextualises the aims of this research. A historical overview of spatial and immersive music practice identifies works by composers who have applied immersivity specifically in their music. A review of technologies and the specific music practices that have allowed this field to develop have been investigated to offer further insight and perspective. Practice-based/led methodologies along with effective participant questionnaire procedures, have been assessed to support the inquiry undertaken in this study in the form of primary research. Each chapter provides a summary to highlight how the literature review has influenced this study whilst identifying any gaps in research. The final chapter in this section specifies the contributions to knowledge and practice realised in this study.

Section B (chapter 7) provides a taxonomy of immersive characteristics that can be applied in music performance. This has been accomplished through an examination of established academic research (the previous practice and approaches) which have determined the key immersive parameters to be investigated. The taxonomy has been devised from a thorough

literature review, which is further supported and informed by the primary research conducted in section C.

Section C (chapters 8 to 11) discusses the three original projects created as approaches to primary research. These were developed to critically examine the application of immersivity in music performance and its potential validity, whilst considering previous practice and the audience. Each project highlights its novel investigative intentions against the research questions and provides synthesised outcomes before deductions are established for further examination.

Section D (chapter 12) summarises the outcomes of this study against the research questions. It highlights what this study corroborates and contradicts against previous theories established in the literature review and the new taxonomy of immersive characteristics. It also reviews the effectiveness of this study's contribution to knowledge in this field before establishing key research areas that require further investigation.

1.4 - Research Questions

Throughout this process, the research questions have been continually developed to reflect the knowledge and experience gained by the author through academic inquiry and performative practice. Several iterations existed before forming these questions in order to effectively investigate the central objectives of this study as fully as possible. In addition, these questions reflect the contribution to knowledge and practice this paper addresses:

1) **How can the concept of immersivity in music performance be better defined through a taxonomy of characteristics?**

2) **What does the composer need to consider in the design and delivery of an immersive music performance project?**

3) **What deductions can be drawn from the application of immersivity in music performance through original works?**

The first research question is be predominantly investigated through a literature review of past works and established theories on the application of immersivity in music performance. Outcomes from primary research in the form of original works that investigate the application of immersivity in music performance, inform the suitability of the final taxonomy. The second research question draws influence from previous works whilst incorporating immersive characteristics developed by question one to ascertain their validity. Research questions two and three jointly form the foundations for the execution of primary research, which consists of three original and unique investigative projects (section C). The methodology for these projects takes the form of four phases (chapter 8) to demonstrate consistency in performative practice. It should be noted however, that due to the absence of a clear theoretical definition for immersivity in music performance from previous studies, the extracted theories from the literature review (as listed in chapter 7), require primary research for them to be appropriately corroborated. It is through this holistic approach that knowledge of this music performance paradigm can be better defined and understood.

Section A

Literature Review

2.1 - History of Spatial and Immersive Music

This chapter introduces the composers and works that have been instrumental in the field of spatial and immersive music. Landmark works will help to establish common practices and ground-breaking experimental methods as well as highlight any potential gaps in research practice. The purpose is to contextualise this field so that this paper can draw from previous approaches and identify areas in which it can contribute to knowledge.

The works have been organised in a largely chronological order, from early to current, highlighting how composers deployed the spatial characteristics of the performance space, together with innovative approaches in the arrangement of the performers and audience within them, including the movement of musicians. Evolving technologies such as tape, mixing consoles, and loudspeaker technology allowed later composers to fuse traditional instruments and electronic sounds in new approaches, thereby attempting to envelop their audience with increasingly larger loudspeaker arrays, whilst moving sound sources within a soundfield in both Acousmatic and Sound Diffusion works.

Computer technology further enhanced the composer's capacity to explore and manipulate the 3D sound-field and fully envelop the audience, both in live performance and digital media using Binaural and Ambisonics technology. The term 'Spatial Music' refers to a music practice that employs spatialisation techniques such as the placement and movement of sound sources withing a given performance space (a sound source can be a live instrument, or a sound emanating from a loudspeaker). 'Immersive Music' has no clear definition thus far, but as explored in this study, it encompasses musical characteristics such as a listener's proximity to sound sources, feeling enveloped by sound, audio-visual clarity, and audience engagement.

The idea of immersion in music may be a new application that is closely related to developments in technology as well as performance techniques, but the use of space in music performance is not new, it has always been important. Spatial features in traditional and religious music within carefully designed architectural spaces may represent the first form of spatial music [Bates, 2009, p.114]. Call-and-response performances (antiphonal) are ancient practices, and there are examples of these in the 4th century Catholic Church, and even further

back to the chanting of Psalms in biblical times [Zvonar, 2005, p1]. A technique called '*cori spezzati*' was used by Adrian Willaert in the piece *Vespers* (1550), a type of antiphonal piece that featured a musical dialogue between two separated choir and instrumental groups [ibid.]. Similarly, Bela Bartok's *Music for Strings, Percussion & Celeste* (1936) placed the strings antiphonally on either side of the stage [LA Phill, 2021]. Music delivered in large cathedrals coloured by structural reverb created a larger encompassing sound, whilst incorporating spatial features by arranging performers in different sections of the space, [Ainlay et al, 2004, p11] composers were able to embed immersive parameters within their music.

> *"Wagner wrote mighty works for orchestras so large that musicians had to play under the stage, in the foyer, and scattered around in the audience!"* [ibid.]

Requiem by Berlioz (1837) is a religious work which uses a tremendously large orchestra in addition to four large brass sections at the four cardinal points. He composed the work with the space in mind, knowing which hall the music would be premiered in, and therefore incorporated its spatial characteristics into the work - something he referred to as "architectural music" [Bates, 2009, p.117].

In *Symphony No 2* (1894), Mahler employed a creative use of space to add impact and interest in the final movement by placing additional musicians carefully off-stage for a dramatic effect [ibid, p.118]. *The Unanswered Question* by Charles Ives (1908) goes a step further by using the space to accentuate the emotive character of the composition, doing so by placing 3 distinct instrumental layers (strings, woodwind and brass) in different sections of the hall. The strings were placed off stage carrying low held triads with a solid harmonic movement, a solo trumpet was placed above on a balcony to represent the questions, which were answered by the woodwinds on stage. Ives give us an indication of his creative decision making with regard to his impression distance gives through his production notes, in which he asserts that "music seems too often all foreground even if played by a master of dynamics" [ibid, p.120]. In 1910 Igor Stravinsky placed tubas in the corridors of the auditorium for his ballet *The Firebird* [ibid, p.120].

Henry Brant, who may be considered one of the pioneers of spatial music, has composed 76 spatial pieces. He regularly separated performers and instrumental groups with the aim to create timbral and textural differentiation to provide compositional clarity, or in his words "to make complexity intelligible" [Harley, 1997, p.75]. Brant outlined his use of spatial characteristics in an article for *Contemporary Composers on Contemporary Music.* pp. 221-242, quoted by Bates [2009, p.121] as:

- *"The perception of different layers of musical material can be enhanced by the spatial separation of the performers.*
- *Exact rhythmic coordination is difficult to achieve when musicians are spatially separated by large distances.*
- *Spatial separation is equivalent to pitch separation but allows for greater complexity as material in the same harmonic range which would merge if produced from the same location, can be separated into distinct musical lines if the sources are separated in space.*
- *Each situation and listening position is different, and there is no single optimal listening position.*"

In his work *Antiphony I* (1953), he divided five groups into different parts of the hall, performing material of contrasting tempo, meter and harmony (it would have been counter-active to the concept of spatial music if all five groups were placed on stage) [Harley, 1997, p.71]. Serocki's Continum (1965-6) uses similar techniques, with six percussionists specifically allocated in different locations within the concert hall [ibid, p153]. In his progress notes, Brant comments that *"*spatial arrangements in music have an essential purpose and plan", which is clearly evident in his work *Millennium II* (1954) - where the conductor, brass and percussion are placed on stage with a single voice placed up on a balcony [1979, p.2]. An additional spatial element was employed by using trumpets and trombones along the walls to move up and across the hall in a programmed manner. This spatial movement was enhanced by using independent layers that employed a mixture of dynamics and dissonant harmony [Harley, 1997, p.75].

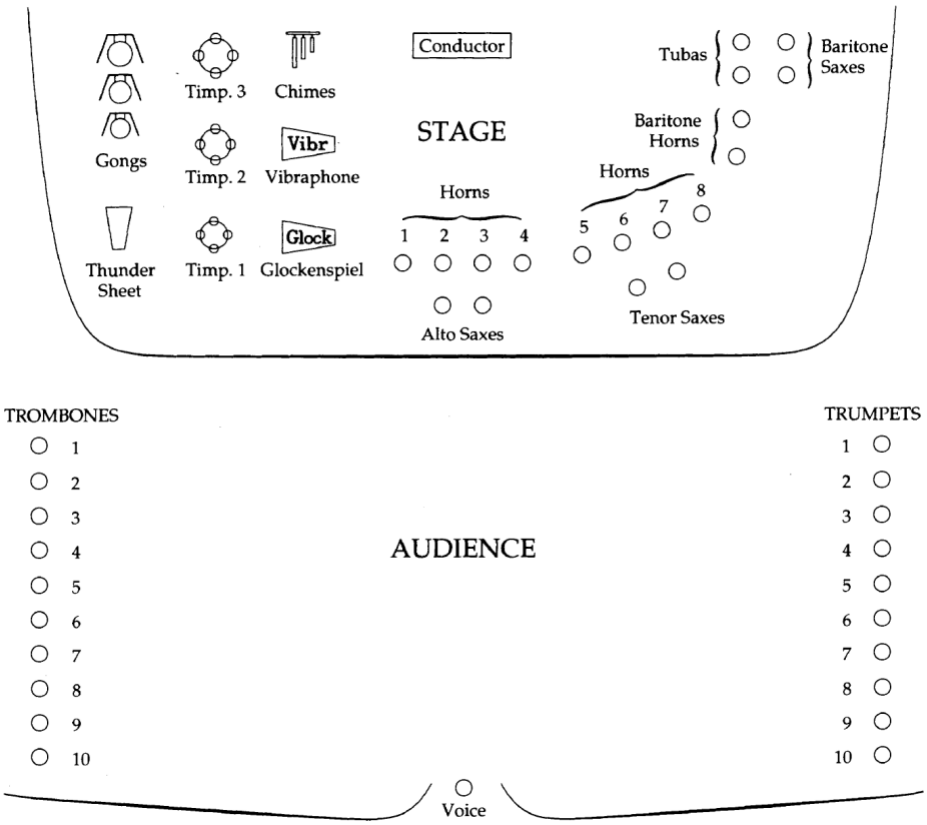


Figure 1.1 – Spatial arrangement of musicians in *Millennium II* (1954)

[Harley, 1997, p.76]

It is worth mentioning Brant's ambitious work *Brandt aan de Amstel* encompassing most of the city of Amsterdam for the 1984 Holland Festival, which was performed only once by a youth jazz band, two choruses, two brass bands, four street organs and four boatloads of performers moving through the city's canals [ibid, p.81]. Brants works demonstrate his experimental and innovative practices to develop spatial music. Other notable works of his include *Windjammer* (1969), where a solo horn player was surrounded by wind players provided with a prescribed performance route. His work *Voyager Four* (1963) employed a far more complex system in which three conductors directed percussion and brass on the stage, violins on one balcony opposite violas, cellos on the other, woodwinds at the rear balconies, basses on the floor, and a few performers within the audience [Zvonar, 2005, p2].

John Cage may have made similar assertions laid out by Brant and Ives, that there is more musical clarity when the speakers or performers are spatially separated. This is demonstrated

through his experimental works including *Williams Mix* (1952), *Earle Brown's Octet* (1952) and *Morton Feldman's Intersection* (1953), in which "eight unsynchronised monophonic tape machines positioned equidistantly around the auditorium, (projected) multiple independent musical layers" [Bates, 2009, p124].

By 1951 developments in *Musique Concrete* by the composer Pierre Schaeffer introduced new techniques in spatial music such as four speaker projection and the use of tape [Bates, 2009, p.128]. The practices of *Musique Concrete* were summarised by Schaeffer in 1952, in which he introduced the idea of 'sonic trajectories' – the manual control of sound moving within a space [ibid.]. An example of this practice was demonstrated in 1951, in which four loudspeakers in a cross formation (front, left, right and back) projected recorded material, whilst a supplementary fifth speaker placed overhead was spatialised by a diffuser [ibid]. This is an early example of constructing a 3-dimensional acoustic space. Along with Schaeffer and Henry, other notable composers in the field of concrete music within the acousmatic medium are Luc Ferrari, Francois Bayle and Bernard Parmegiani. The latter credited for his innovative approaches, especially in his masterpiece *De Natura Sonorum* (1975) which countered natural sounds against artificial ones.

The work of Pierre Henry in the 1950s using *Musique Concrete* practices formed the basis of live 'Sound Diffusion' (which employs spatialisation techniques), and later influenced notable composers such as Dennis Smalley and Ambrose Field. Henry used a selection of loudspeakers arranged in the auditorium to perform recorded material distributed using a 'diffusion desk' [Zvonar, 2005, p11]. In 1996 Henry's work *L'Apocalypse de Jean* (1968) was diffused through a 24-speaker array with the addition of six subwoofer channels [ibid, p11].

> *"The main interest is not in moving sound around in space but rather the articulation of the music through performing different passages through differently sounding arrays of speakers. Thus, a sound which is massive and threatening in character might be sent to a pair of very large cabinets positioned far upstage, and then gradually introduced into a larger number of speakers surrounding the audience, while simultaneously increasing the*

subwoofer feed. Similarly, a delicate sound might be circulated through a battery of very small tweeters suspended overhead." [ibid, p11]

Stockhausen took many of these new ideas and implemented them in his own work such as *Gesang Der Jungelinge.* It premiered in 1953 and used five sets of loudspeakers, four sets surrounding the audience and one on stage [ibid, p.128]. This serialist piece fused electronic synthesized elements with natural recorded sounds, whilst the combination of speaker arrangements and mixture of timbres was hugely innovative at the time. With reference to Stockhausen's compositional approach, Bates [2009, p130] defines his ideas of 'total serialism', which goes beyond Schoenberg's initial 12-tone row (pitches), to include a series of rhythms, timbres and space.

Stockhausen demonstrated his innovative methods further in the piece *Gruppen* (1955-57). To this day, it remains an important piece of 20th century music and an aspirational project for many conductors due to its complex arrangement and delivery, in which three orchestras and three conductors are placed around the audience [ibid, p.133]. *Carre* (1959-60) is another noteworthy piece, which placed four orchestras in a square around the audience [ibid, p.134].

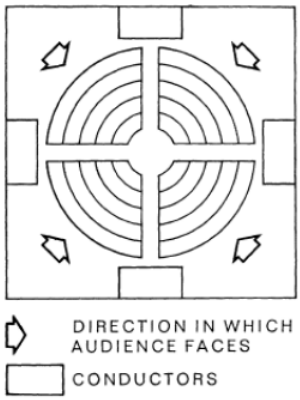


Figure 1.2 – *Carre* (1959-60), [Bates, 2009, p.136]

Although Stockhausen composed many other significant works, one of his most ground-breaking is considered to be *Kontakte* (1961). This was an electroacoustic work using four loudspeakers in a crucifix formation projecting pre-recorded material alongside percussion and piano, with the instrumentalists requiring a click track to remain in time with the tapes

[Bates, 2009, p.137]. This may now seem common practice, but it is extraordinary to think that Stockhausen's ambitious works constantly pushed the boundaries of performance and use of technology. Another such example is *Stimmung* (1968), which had six amplified vocalists projected through loudspeakers that surrounded the listener at the centre [Zvonar, 2005, p4].

Sirius (1975-77) used a square auditorium with the audience facing the centre, performed through an 8-speaker array using diffusion of electronic elements to exaggerate the spatial movement of the projected sounds, in addition to four live soloists (trumpet, soprano, bass clarinet, and bass) placed high on opposite sides of the auditorium [ibid, p.136]. His idea for *Sirius* was explained in an interview -

> *"Sirius is based entirely on a new concept of spatial movement. The sound moves so fast in rotations and slopes and all sorts of spatial movements that it seems to stand still, but it vibrates. It is [an] entirely different kind of sound experience, because you are no longer aware of speakers, of sources of sound – the sound is everywhere, it is within you. When you move your head even the slightest bit, it changes color, because different distances occur between the sound sources."* [Felder, 1977, p.87]

The year 1958 brought the Philips Pavilion Expo and important contributions by Xenakis and Edgard Varese [Zvonar, 2005, p5]. Although Xenakis was not classically trained as a composer, he was able to produce some major works in the field of spatial music. *Metastasis* (1954) used 65 musicians (wind, percussion, strings) all of which had individual parts playing independently. The musicians performed glissandos at different pitch levels [Berner, 2008, p50], delivering a rising dissonant intensity reminiscent of the Shepard Tone (an auditory illusion, that creates the impression of a continually rising or descending pitch). Xenakis did not compose works for the Philips Expo, but the visual shape of the graphic score used in *Metastasis* influenced the architectural structure of the Pavilion. Instead, the Pavilion projected through 425 speakers the work of Edgard Varese called *Poème électronique* (1958), which was spatialized through an elaborate switching mechanism to activate nine different groups of loudspeakers [ibid.]. Xenakis carried on composing music for immersive

environments, such as his work *Terretektorh* (1965-66) which used 88 musicians in a circular arrangement with the audience distributed within them [Bates, 2009, p142]. It is worth mentioning that Xenakis' interests went beyond composition and spatial music. His multi-sensory interests are unified in his idea of *Polytopes*, a combination of sound, light, colour and architecture; of which he composed many throughout his career [Fabrizi, 2014].

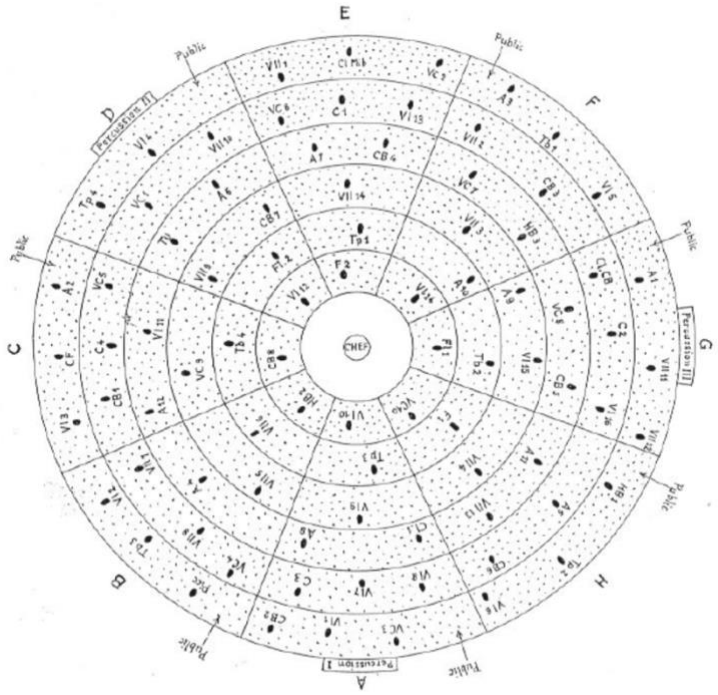


Figure 1.3 – *Terretektorh* (1965-66), [Bates, 2009, p.142]

In the *Genesis Cycle* (1962), Gorecki arranges the orchestra in different geometric shapes, and then repositions the audience between each movement with the aim to create spatial trajectories [Mirka, 2004]. The *Genesis Cycle* which includes *Elementi pertre archi* (1962), *Canti strumentali* (1962), and *Monodram* (1963), dictates specific spatial arrangements for all the performers [ibid, p305]. Figure 1.4 demonstrates the geometrical arrangements of the performers in *Canti strumentali,* where the conductor (D) is in the centre position; from that centre line you can see the mirroring of the instruments in the outer geometric shapes. Mirka highlights that composers tend to think of the performance space in 2-dimensions, because that can be easily represented in a score. However, Gorecki was far more interested in 3-dimensional space, which is not only reflected in his spatial arrangements, but also in his unique representation of depth in his scores [ibid, p305]. Mirka questions whether the

notation seen in figure 1.5 is Gorecki's "attempt to organise geometrically the vertical dimensions of the stage" [ibid, p313].

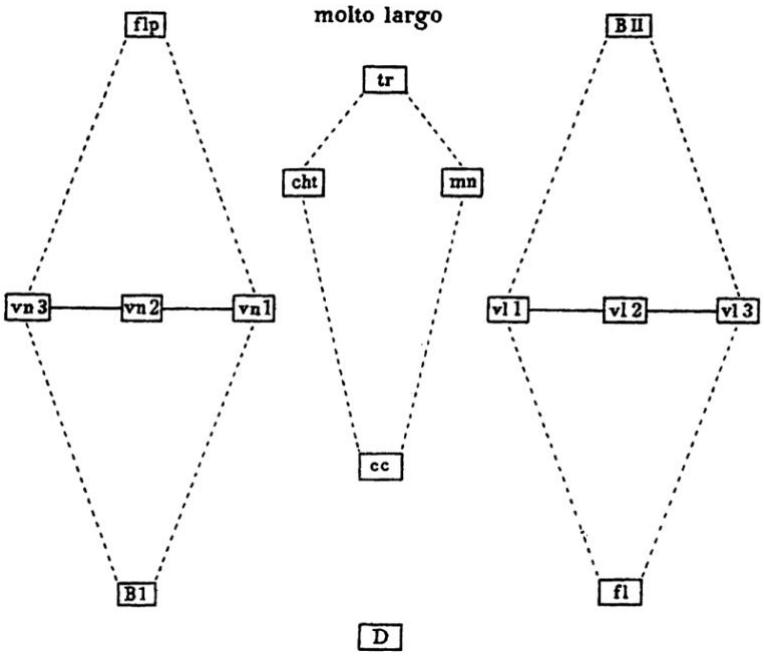


Figure 1.4 – Arrangements of musicians in *Canti strumentali* (1962)

[Mirka, 2004, p308].

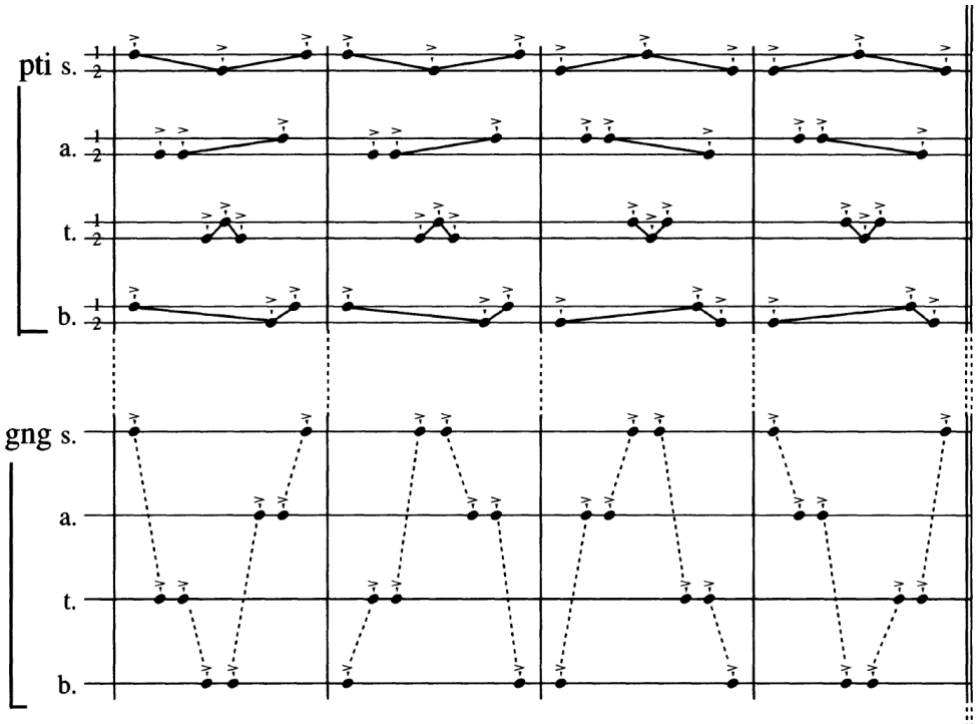


Figure 1.5 – Segment of score from *Monodrama op. 19* (1966)

[Mirka, 2004, p310]

John Chowning completed *Turenas* "one of the monuments of computer music " [Zvonar, 2005, p8] in 1972 after many years of research in sound localisation and frequency modulation (building his own systems to realise his musical aspirations). Chowning along with a computer scientist collegue were able to build a computer simmulation of sounds travelling through space, allowing them to calculate the trajectory of sound [Ibid.]. In Chowning's own words [Chowning, 2011, p1], the "illusory motion of sound in space was a musical goal"; this goal was to "compose sound in space that was free of physical constraints and realities, yet would evoke auditory images that were believable" [ibid, p10].

> *"Chowning went on to develop a real-time digital implementation of the system using a standard Quadraphonic loudspeaker array. The inclusion of the Doppler effect and other secondary cues such as high frequency air absorption, when combined with independent control of the direct and reverberant signals resulted in an effective simulation of movement which was highly sophisticated for its time"* [Bates, 2009, p63]

The development of tape as a method to project pre-recorded material gave many experimental composers a new delivery format in which they could explore the compositional capabilities of a performance space. *The Palace* (1978-80) performed by baritone Phillip Larson, used quadrophonic technology to project his recorded voice through speakers that surrounded the audience whilst he sang alternating passages from the stage [Zvonar, 2005, p9]. The piece *Watershed IV* (1996) by Roger Reynolds uses a 6-channel system with four speakers panoramically arrayed on the stage, and the other 2 acting as Left and Right; live percussion is recorded and spatialised within the auditorium in real-time to create various spatial illusions [ibid, p9-10]. Although *Canadian Coastlines* (1983) by Larry Austin did not specifically employ spatialisation techniques, it did provide some innovative approaches, where the compositional elements were "determined by a graph of the Canadian coastline" [Dominick, 1982, p179]. Eight musicians performed eight 'canonic' parts, four live and four pre-recorded, with each voice performed at a different tempo and "organised to coincide five times during the piece" [ibid.]. However, Austin used octaphonic setups with sound diffusion techniques to immerse the listener regularly in his work, including *Djuro's Tree* (1997), *Les Flûtes de Pan: Hommage à Debussy* (2005-6), and later *John Explains…* (2007), which uses

passages from an interview with John Cage as the main compositional material [Gottschalk, 2016, p85].

At the 1970 world fair in Osaka, the Japanese Steel Pavilion called *Hibiki-hana-ma* used 8-channel tape performed through 800 speakers arranged all around the audience, overhead and underneath [Bates, 2009, p.142]. At the German Pavilion, Stockhausen "and a group of 20 soloists performed two concerts a day for 183 days in a blue steel spherical auditorium 28 meters in diameter, holding an audience of 600" [Zvonar, 2005, p5]. The audience was placed on a sound transparent grid and enveloped in sound by a spherical loudspeaker system above them, with soloists placed high up on separate balconies [ibid.]. Maybe neither the German nor Japanese Pavilion could compare with the Pepsi Cola Pavilion in creating a fully immersive experience.

> *"The fixed speaker installation the pavilion offered a large number of Handsets which could be carried around the space. Each Handset picked up audio material by means of an electronic induction system, so that 11 zones within the space represented different sonic environments which could be "tuned-in" to by the bearers of the device. In addition to the sound system, the pavilion had a rich array of optical and environmental effects such as laser beams and dense fog. The interior of the dome had a mirror finish, providing an ever-changing distorted image as performers and the public moved about the space. Because the pavilion was designed as an adaptable instrument, much depended on the choices of the programmers. In all, there were twenty-four artist/technologists chosen for this task. They ranged from musicians and sound artists to light (or "lumia") artists to dancer/choreographers."*
>
> (Zvonar, 2005, p6)

A culmination of many of the techniques discussed thus far were integrated by Pierre Boulez in his grandiose piece *Repons* (1985). This highly ambitious work of electroacoustic music places a 24-piece orchestra in the centre of the auditorium with the audience in-the-round, surrounding them. Six satellite soloists and six loudspeakers are placed above the round, closer to the auditorium walls surrounding the audience and orchestra. Boulez attempted to

create real-time spatialization with the six soloists captured electronically and circulated in specific trajectories by the loudspeakers. The effect meant that the audience would find it difficult to localize the paths of the individual sounds, whilst creating separation between the central orchestra and the soloists [Bates, 2009, p.162-63]. It is unsurprising that due to its large-scale and specific venue requirements, *Repons* is not performed frequently [ibid. p165].

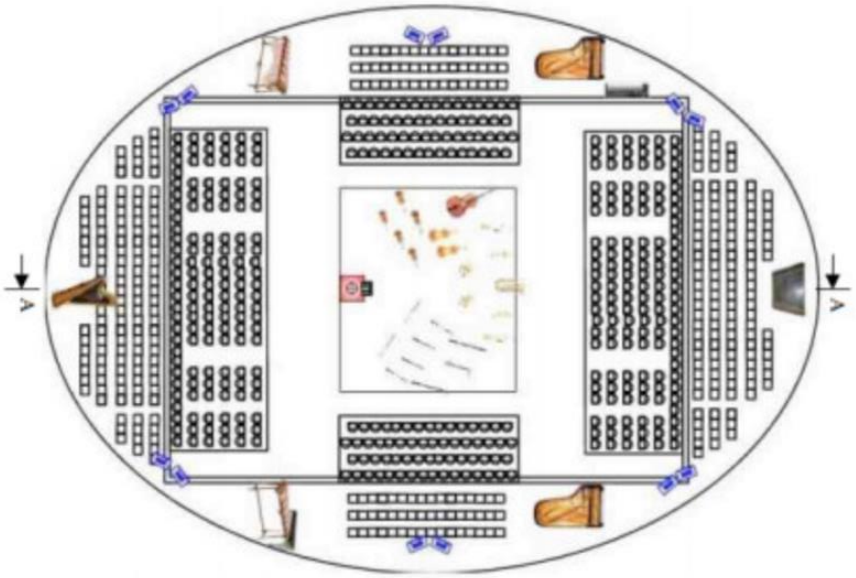


Figure 1.6 – Arrangement of Repons by Boulez (1985)
[vagnethierry.fr, 2013]

In his piece *Dialogue de l'ombre double* (1985) Boulez creates a live dialogue between two clarinets, one live and un-amplified placed in the centre of the hall and the audience, and one pre-recorded projected through a 6-speaker array surrounding the audience, with additional lighting to emphasise the contrast between the two performance paradigms [Bates, 2009, p166].

Barry Truax is a pioneer and proponent of 'soundscape music', a style of electroacoustic music that focuses on realising acoustic sound environments with an emphasis on audience perception [Truax, 2012, p2]. Truax uses the term 'acoustic communication' to refer to the study of "how information flows between listeners and their environments, and how sound creates relationships, both personal and social" [ibid]. He has composed a vast number of

works, some specifically for 8-channel tape spatialised through 8-speaker surround sound arrays using the DM8 computer-controlled diffusion system developed at Simon Fraser University [SFU, 2021]. One such work is *Basilica* (1992), which stretches the sound of the bells recorded at the Quebec City cathedral to give the listener the impression that they are entering the space themselves [Truax, 2012, p10], whilst Pendlerdrøm (1997) recreates a commuter's trip home in the city of Copenhagen [SFU, 2021].

Jonty Harrison, a professor at the University of Birmingham, is the director of the Birmingham EletcroAcoustic Sound Theatre (BEAST) and a notable electroacoustic composer using sound diffusion techniques. Harrison has composer several pieces for octaphonic tape including *Streams* (1999), which utilises the 'main eight' system deployed at BEAST [Mooney, 2005, p135]. *Streams* is a sound exploration of the various forms and motions created by water, which later becomes part of a series of works called *Internal Combustion* (2005-06), with each of the four pieces in the series using "slightly different configuration of 8 audio channels and explores different aspects and types of motion, trajectory and spatial organisation" [ibid.].

In Truax's *soundscape music*, it is important that the natural sounds are preserved and not manipulated to accurately represent that environment. However, in some forms of electroacoustic music such as acousmatic and sound diffusion, those original sounds are mangle until they are no longer recognisable. In Ambrose Field's *Still Water* (1994) which uses a loudspeaker orchestra, the work gradually transitions from one soundscape to another, i.e., from the natural to the electronic.

> *"I wished to create the sound of a large, open environment. I start with the sound of a beach that sounds like somewhere in the south of France. It's actually the Serpentine Lake in central London, carefully re-processed. The waves lap up against the shore, and you can hear some seagulls, and you can hear some sand rustling. Now, I wanted every recognizable element of that soundscape to change into an abstract, unrecognizable sound, but over different time scales. So, gradually the seagulls become masked, the sound of the waves becomes slightly more electronic, and over the course of about a minute they change into a vast granular texture."* [Austin, 2001, p25]

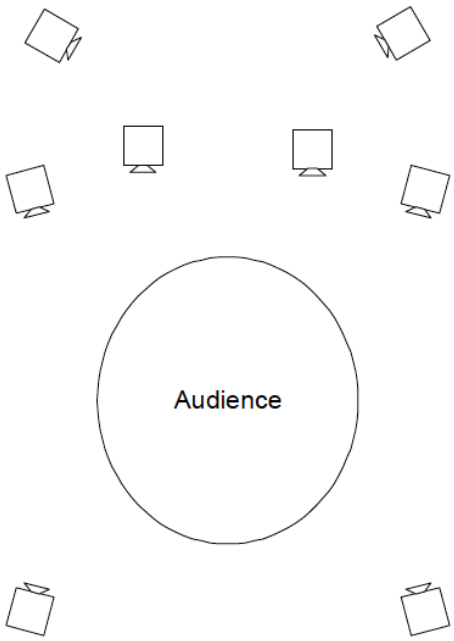


Figure 1.7 – BEAST 'main eight'

[Mooney, 2005, p135]

As technology became more sophisticated, composers were able to employ larger loudspeaker arrays with greater control using specially designed hardware and software applications. Binaural technology has become a standard for headphone-based immersive audio. Ambisonics is a type of recording format that affords composers full control of sound sources within the 3D sound-field, whilst also making the work fully portable, and can be performed on a variety of different loudspeaker arrays [Austin, 2001]. Ambisonics has therefore become popular for live spatial works, in particular acousmatic music, but also blended format pieces that incorporate both live musicians and live diffusion over loudspeaker orchestras.

Natasha Barrett is a highly experienced composer of spatial music employing Ambisonics technique in numerous works using First and Higher order Ambisonics. She is a fervent exponent of the method in both her music practice and as an academic. Her investigation into spatial music has yielded a comprehensive number of acousmatic works. One of her earliest, the *Utility of Space* (2000), is an exploration of musical structure through the spatial qualities

of sound material such as locations, trajectories and magnitudes; the piece was composed and performed using Ambisonics decoded for a hexagonal array [Barrett, 2021]. The adventurous *Exploratio Invisibilis* (2003), was decoded for 12 speakers spherically arranged around, above and below the audience, and spatialised using 2nd order Ambisonics.

> *"Exploration Invisibilis carries the listener on their own 30-minute voyage through a three-dimensional energy filled electronic landscape of implication, sound and silence"* [ibid.]

Microclimates III-VI (2007) comprises of field recordings of four different soundscapes. Barrett recorded these soundscapes without a Soundfield microphone, instead using multiple microphones to capture the essence of each environment. Using 3rd order Ambisonics the material was encoded for performance over a 3D 16-speaker array, with eight loudspeakers in a central ring around the audience, and four additional speakers above and below (figure 1.8). Two versions of this piece exist, one as an installation and the other as a concert work [ibid.].

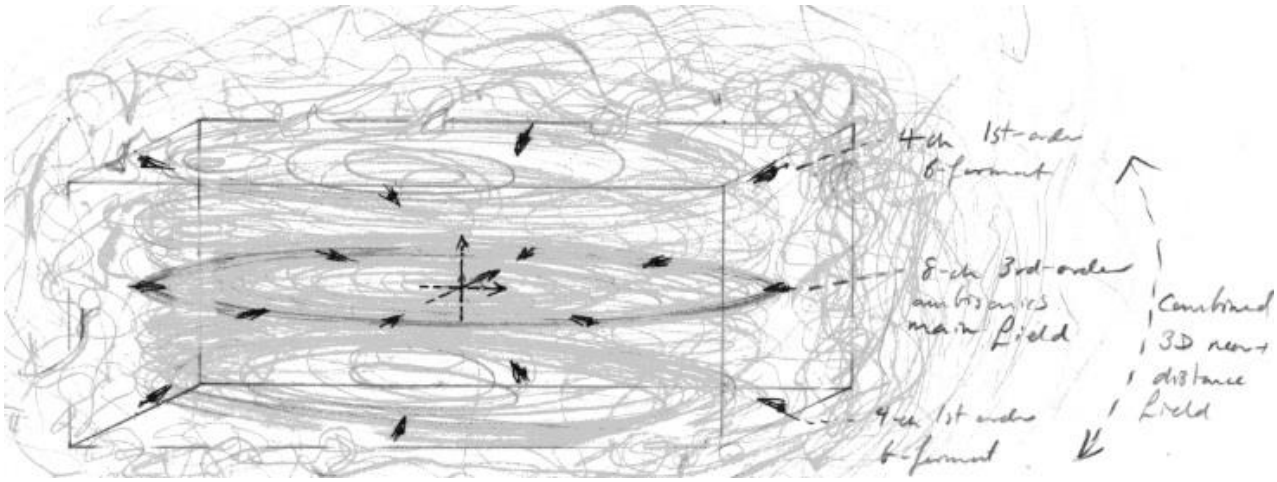


Figure 1.8 – Loudspeaker arrangement for *Microclimates III-VI*

[Barrett, 2021]

What is interesting about her piece *Kernel Expansion* (2009), is that the spatialisation technique uses a "hybrid Ambisonics format, where some source materials were recorded with a Sound-Field microphone, and other materials were synthesised in higher-order

Ambisonics" [ibid] - which further demonstrates the flexibility of the format. The piece was performed using the 43-loudspeaker system available at the Klangdome concert hall in Germany. In 2018, her piece *Dusk's Gait* explores 7th order Ambisonics, and can be performed through various loudspeaker arrays from 8 to 64 speakers, including traditional sound diffusion for Acousmonium - a system devised by Francois Bayle in 1974. Barrett explains that the piece is an appreciation of the natural world, where the spatialisation techniques used create "tangible spatial objects, … with a characteristic gait" [ibid.].

In *String Quartet No. 1* by Enda Bates, an amplified quartet is placed at the front to provide a strong visual focus, with the electronic parts used to "extend and widen the acoustic sound of the quartet from the stage and out into the hall" [Bates, 2009, p176]. The primary goal was to trigger (in time) and seamlessly blend the various synthesized electronic parts with the natural sound of the quartet. Using a Max MSP patch, the key role of the live diffusionist was to adjust the dynamics so that the electronic part should "colour" but not dominate the quartet [ibid, p291]. In this composition Bates employs a similar idea to the Shepard Tone to create and endless ascent - as there is no clear tempo, a click track is not used. The string quartet and diffusionist are provided with separate scores, with guidance on how to extend the azimuth settings of the electronic parts in different sections of the piece, as seen in figure 1.9 [ibid]. The piece was performed primarily using a preferred 8-channel loudspeaker array, but can be performed in a variety of large orchestra situations, with the electronic parts spatialised using higher order Ambisonics [ibid, p181].

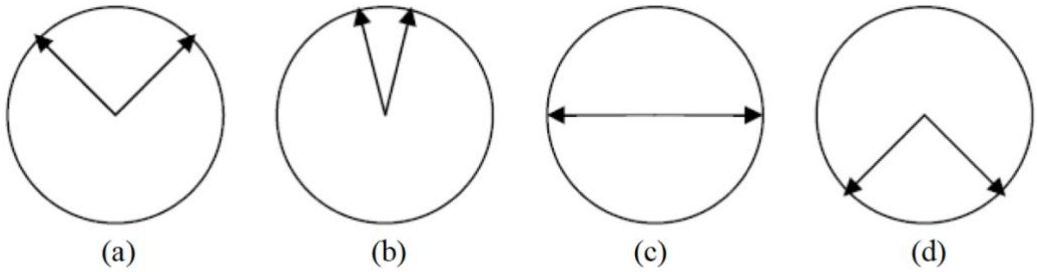


Figure 1.9 – *String Quartet No. 1* Azimuth directions
[Bates, 2009, p291].

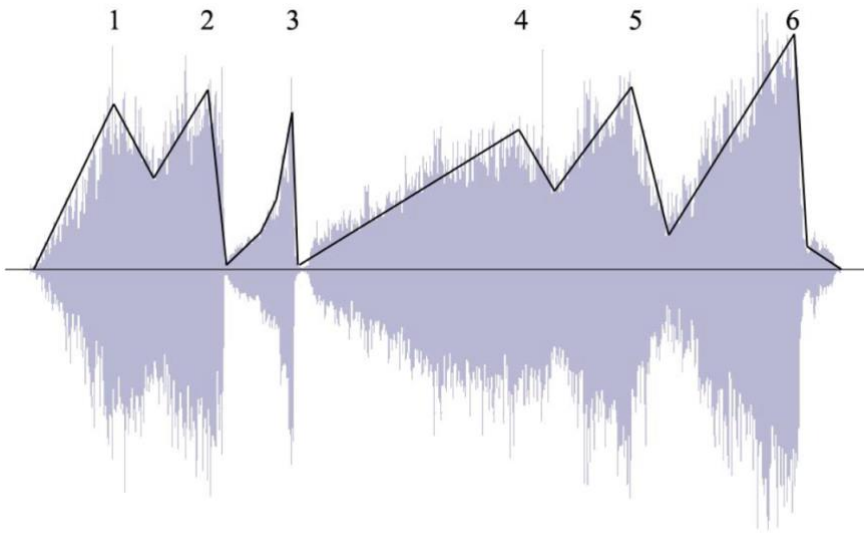


Figure 1.10 – *String Quartet No. 1* Dynamics

[Bates, 2009, p197].

Bates took part in the Trinity360 series (2019), in which *Spem in Alium* was performed by the New Dublin Voices specifically for 360 capture and processing for video [Bates, 2019]. This is a technique widely used (including this study) for immersive audio using binaural technology, particularly for listening back to the soundfield recordings of a live performance on headphones. For this performance a soundfield microphone (ST450 MkII) was placed in the centre of the performance space; eight additional cardioid microphones arranged octagonally with 45˚ angle separation facing out from the centre; and a GoPro Omni 360 camera for video footage. The choir was arranged in a circle facing inwards towards the microphones. The audio is then processed using first order Ambisonics (FOA) and stitched together with the video footage for a 360 VR experience using YouTube 360 technology.

The composer Ed Wright explores various methods to write for mix-method and mix-media material, such as blending live orchestra instruments with loudspeaker projected electronics. *Harpset* (2007) is an 8-channel surround piece accompanied by moving image, with the aim that the audio reflects the physical movement of the squares presented in the film [Wright, 2021]. In Polarities (2009), Wright attempts to bridge the gap between a live orchestra and pre-recorded material projected through a surround sound 8-speaker array. In the sound installation piece *Who Can Hear the Sea* (2012), eight audio loops comprising of recordings of the sea (isolated so that they do not include other natural sounds), are projected through an

8-speaker surround sound system. The simultaneous performance of each loop, each comprising of different lengths, creates a continuous ever-changing soundscape which would eventually return to the beginning after approximately 1875 years [ibid.].

The artist Bjork has continued to challenge the boundaries of musical artistry by embracing technology through various mix-media and sound-art works presented as innovative albums, applications, installations and live performances. In 2011 Bjork released her 7th studio multi-media concept project *Biophilia*, an album of ten songs concerning nature and our relationship with it. The album was accompanied by an application (for both iOS and Android), with ten separate apps for each track, and billed as an education project which included an introduction by David Attenborough [Biophilia, 2021]. Her next record *Vulnicura* (2015) was accompanied by the immersive exhibition 'Bjork Digital', which allowed audiences to explore her music videos in 360-degrees using VR headsets, such as the intimate one-2-one *Stonemilker* video, which places the listener along Bjork on a remote beach in Iceland. Potentially her most ambitious work of all is the concept tour *Cornucopia* which premiered at The Shed (a flexible performance space) in New York in 2019. In the 100-minute, 19-song set, Bjork is accompanied on stage by a 50-person choir, flutes, harp, various percussion instruments, electronics and a reverberation chamber - all realised on a layered stage with a 360-degree sound system. Bjork's aim was to create a unique multimedia event that combined music performance, a 3D sound environment, theatre and visuals. The choir would leave the stage and move along the audience to create an evolving soundscape as their voices would reverberate throughout the performance space. The *Cornucopia* tour used a specifically designed 3D speaker system by *d&b audiotechnique*, which itself continued to take new shapes depending on the venue [prosound, 2019].

> *"Cornucopia became an all-immersive world and is still very much a music event, so it became apparent that while the show would have these transparent and quiet moments, it would also have moments of a fully immersive audio concert with music enveloping you from all corners of the room."* [ibid.]

2.2 - Summary

The space in which a musical project is delivered has an influence on the sonic outcome, and thus, cannot be separated by the manner in which the music is perceived by an audience. It is clear that many early composers recognised this fact, and therefore used the spatial and architectural characteristics of a space in innovative ways. Interesting spatial arrangements of performers and audience were further enhanced through the movement of musicians. This demonstrates a long-standing experimental practice with space, including spatialisation and envelopment techniques. These are just some examples of works in which composers deviated from the traditional front-back format, even before the influence of technology. Such approaches were further enhanced by developments in technology, where room acoustics could be further influenced by loudspeaker systems. These allowed for developments in spatial projections and envelopment through a mixture of live musicians, loudspeaker systems and unusual delivery formats. The continued boundary-braking approaches discussed in this chapter, may be the reason why Emmerson [1993] asserts the notion that at the core of immersive music practice is the attempt to stimulate as many of the senses as possible.

What this chapter demonstrates is that immersive music practice has a long history, one that has been continually developed and shaped by new ideas and technologies, but where the term 'immersive' seems to have not been considered as a descriptor until relatively recently. Nonetheless, it is reasonable to consider how the innovative use of space, including surround-sound systems to increase envelopment, and spatialisation techniques such as the movement of live musicians and virtual sound-sources, can all contribute to immersivity in music performance.

Spatial music, as well as other practices such as acousmatic music and sound diffusion (explained in chapter 4) have recognisable identities through definitive compositional approaches. However, the literature review thus far has not exhibited the same level of understanding with regard to immersive music. It can be surmised from this chapter that spatial music entails inherent immersive characteristics, and therefore theorised that

immersive music is likely to include some application of spatialisation. As a result, those two music practices are intrinsically interlinked. However, it is clear that immersive music consists of other characteristics, proving it to be a complex medium more difficult to define.

The aim of this chapter serves to better understand (and hypothesise) which characteristics have been employed successfully by notable composers to create an immersive music environment. It informs the first research question to some extent, but further investigation is required to meet the research aims of this study, in particular its intended key contribution to knowledge - a taxonomy of immersivity in music performance. The techniques used by previous composers will certainly inform the second research question and influence the original projects developed in this study. But there are two gaps in research practice this inquiry needs to interrogate further. Many of the works described in this chapter exhibit experimental musical approaches, in some cases almost serialist in nature, far removed from the compositional techniques presented in popular contemporary music. In chapter 7 the merits of an audience-centred approach to composition and performance will be explored. Furthermore, none of the works discussed have used participants to better understand how successfully the investigations have been perceived. This is understandable, as many of the works discussed have not arisen from academic investigations, and would therefore not be expected to adhere to research practices. This demonstrates that there is scope to better understand this field through participant responses. These gaps in knowledge and practice discussed are at the core of the investigative aims, which will be argued with greater detail in chapter 6 to contextualise the primary and secondary research presented in this thesis.

3. Technology

"Technology is a social sign whether we like it or not; it indicates power in the form of resources: expertise, manpower or funding" [Harries, 2011, p75]

This chapter outlines the technological developments that have influenced the delivery and consumption of music with particular reference to technologies applied within the scope of spatial and immersive music practice. This discussion enables a critical review of these technologies in relation to the primary research of this inquiry.

3.1 - Mono

The term 'mono' refers to the monophonic (Greek meaning for single voice) reproduction of sound [Roginska et al, 2017]. Before the development of stereophony, monophonic reproduction was the standard, in which the sound of entire ensembles would be recorded using a single microphone within the sound stage. Moylan [2012, p166] explains the *sound stage* as the listeners position against their perception of sound width and depth (figure 3.1). Monophonic recordings suffered from directional information, however, the illusion of space could be created if enough spatial characteristics, such as reflections and reverberation were captured from the sound space [Roginska et al, 2017]. This could be achieved by the timbal characteristics of each sound source presented in the recording, with close instruments obtaining greater detail of higher frequencies, whilst the opposite would occur for distant sources with a lack of definition [Moylan, 2012].

3.2 - Stereophony & Phantom Image

Stereo remains the main commercial system of sound reproduction since Alan Blumlein patented two-channel stereophonic sound in 1931 [Bates et al, 2007, p.2]. The word 'stereo' also comes from Greek, and means 'solid' [Kyriakakis, 1998, p942]. Stereophony's hold on commercial music does not seem to want to loosen its grip as the leading format, with headphones and mobile technology playing an even larger part on its authority in the current climate - remaining the standard playback system since its wider use in the marketplace in

the 1950s [Roginska et al, 2017]. Stereophony's popularity is in its ability to recreate the illusion of spatial characteristics in just two or more loudspeakers [ibid.], which has resulted in hi-fi systems and headphones that are widely accessible to the consumer. The stereo format which uses a two-channel amplitude method to create phantom images across two speakers has been used very successfully in music, and therefore has become a format that we are well accustomed to [Malham et al, 1995, p61]. Composers and producers are able to manipulate and control this image, building on the human ears ability to distinguish localisation and create spatial understanding [Wozlniewski et all, 2006, p144], such as objects moving in a natural environment but with musical sound sources instead. Other elements within the stereo field include "the size of the image, the breadth of the image, and the depth of the image" [Austin, 2000, p14].

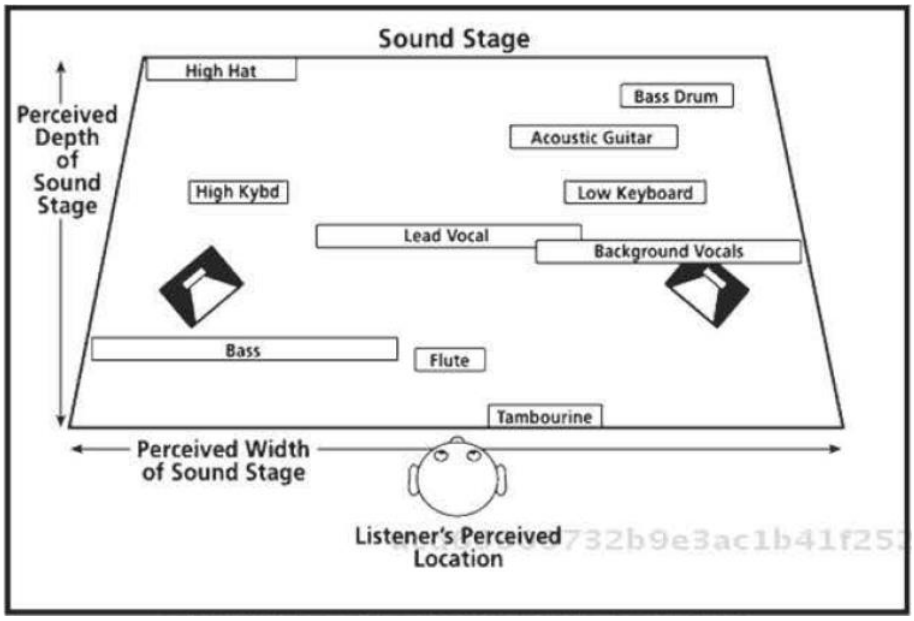


Figure 3.1 – Sound Stage
[Moylan, 2012, p166]

The leading issue with stereophony is that the sound is very directional, and therefore the position of the listener is integral to their perception of the work. Any position that is off-centre will produce poor stereo imaging [Clarke, 2009], whilst large rooms and audiences suffer even more from a lack of sonic equality [Harrison, 1998]. Research and practical experience in stereophony has determined the optimum listening position in 2-channel loudspeaker systems, as an equilateral triangle with the listener at the point of the triangle creating a 30° angle from each speaker (figure 3.2) [Rumsey, 2012]. Any movement outside

of the ideal listening position (sweet-spot), as well as any head rotation will affect the stereo image [Roginska et al, 2017]. Deviation from the 'sweet-spot' will create infinite sonic versions of the material to the audience; what each audience member hears totally depends on their position in the listening space [Dow, 2005, p1]. As Harrison explains:

> *"Even on a good hi-fi system, with the listener in the 'sweet spot', the stability of the stereo image is notoriously fickle – turning or inclining the head or moving to left or right by just a few inches, can cause all kinds of involuntary shifts in the stereo image."* [Harrison, 1999, p3]

Stereo is able to create the illusion of spatial characteristics through phantom imaging, in which the apparent location of the sound source depends on its panning, amplitude and depth [Rumsey, 2012]. Phantom images shift the placement of the source across the 2 speakers through amplitude changes, where the source moves to the speaker with the louder amplitude [Truax, 2008, p105]. This is because the signal emanating from the speakers is heard by each ear with some delay (figure 3.3) [ibid.]. Phantom images will therefore appear solid in the ideal listening position, but will be immediately affected with any changes in position (figure 3.4) [Roginska et al, 2017]. Interestingly, if the sound source is "panned hard left or right (so that) it behaves in a monophonic way", its position will remain in that speaker regardless of the listener's position [ibid].

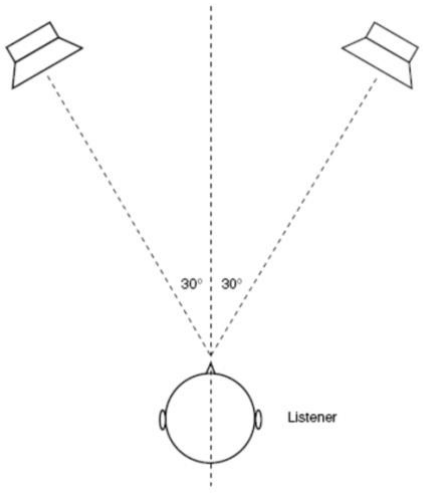


Figure 3.2

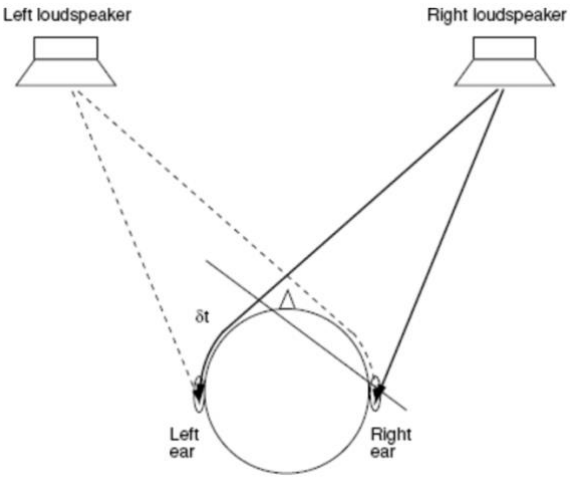


Figure 3.3

[Rumsey, 2012]

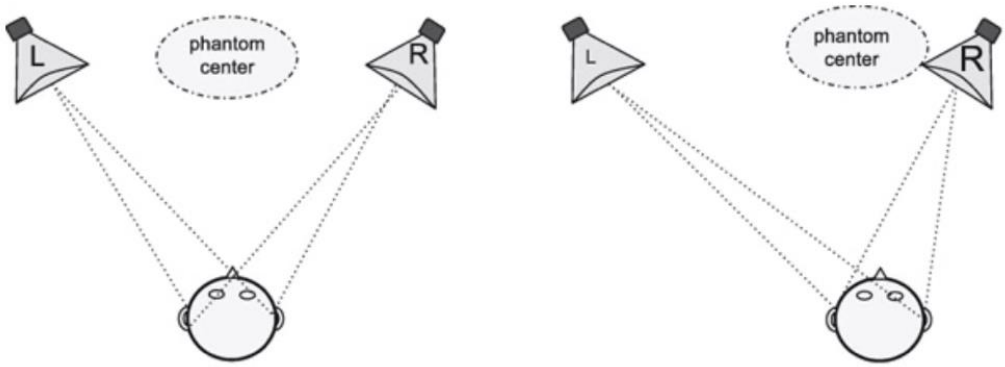


Figure 3.4 - [Roginska et al, 2017]

These issues with stereophony also exist within a performance space, in which our perception of the musical material is dependent on our listening position. Harrison adds that the far reaches on the left or right of the auditorium will provide an unbalanced image, at the far back the listener will most likely get a mono signal, whilst someone at the front will experience a 'hole in the middle' effect, where some of the stereo imaging is not accurately presented [Harrison, 1999]. Conductors for example, have a different sonic image than the audience, yet they are key to what the audience hear, it is therefore impossible to conduct the orchestra for each audience member [Harley, 1999, p148]. Other issues occur in a rectangular space, in which the distance creates an uneven image between those at the front to those at the back [Austin, 2000, p12], whilst the natural reverberation of a space tends to affect the image, decreasing the ability of the listener to determine localisation and directivity [Wozlniewski et all, 2006, p147].

The 2-channel format, whether through a 2-speaker loudspeaker system or headphones remains standard practice, as is the reproduction of music through speaker systems in performance spaces. Even when there is no speaker system such as in orchestral music, we arrange our musicians on a stage in front of the audience, with the sound stage divided to reflect the manner with which we listen to music on a stereo format, or vice-versa. This is what we have come to accept as the ‘traditional front-back’ listening model. With different formats having been introduced through the advent of new technologies such as surround sound, it was widely predicted that stereo would be phased out [Henriksen, 2002]; a prediction which has yet to come to fruition.

3.3 - Binaural Audio

The term *Binaural* relates to having or hearing with both ears. The binaural method simulates how sound is heard depending on the sound-sources direction and distance [Plinge et al, 2018, p1]. As Menzies [1999, p71] explains, the binaural method "aims to create an illusion" of how a listener would naturally hear a space by reproducing that soundfield. Binaural technology has therefore been designed to capture the spatial cues of a soundfield as they would be anatomically, before they are reproduced in the form of stereo [Barnard, 2010, p22]. It could be argued that all stereo is binaural as it deals with 2-channel sound entering a listener's left and right ears. However, for the technology to "mimic human localization cues", the sound must be filtered to combine "time, intensity and spectral cues" [Roginska et al, 2017]. Binaural audio creates an extra dimension in the traditional stereo field, in which audio information encoded with depth and width, also contains elevation. It can provide a more detailed and accurate capture of an environment's sonic characteristics with regard to sound-sources and their position within a 3-dimensional soundfield.

> *"a conventional stereo signal is akin to looking out of a window from within a room, whereas a binaural signal would be like stepping through the window and into a surrounding environment."* [Barnard, 2010, p26]

When we use the term 'surround' we tend to imagine an immersive and enveloping sound experience. Whether by musicians, a loudspeaker array, or on headphones, we are generally trying to recreate the world of sound as we naturally hear it [Hall et al, 2017, p174]. Binaural audio is attempting to emulate this exact feeling. A simple way to create binaural audio is to place two microphones at the position of each ear (figure 3.5). Binaural technology captures spectral cues, that are then stored as HRTFs (head related transfer functions). HRTFs store sound source information against the shape, position and orientation of the ears, head and body [McKenzie et al, 2017, p1].

> *"Head Related Transfer Functions … functions describe the paths between a sound source and each ear of a human listener in terms of a) the interaural time difference (ITD) imposed by the different propagation times of the sound wave to the two (left and right) human ears and b) the interaural level difference (ILD) introduced by the different propagation path lengths, as well as the shadowing effect of the human head."* [Tsacostas et al, 2007, p1]

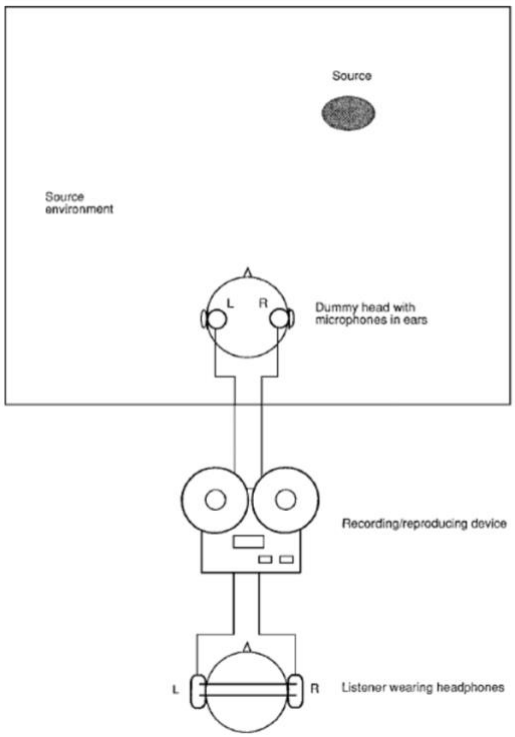


Figure 3.5 – Basic Binaural recording & reproduction
[Roginska et al, 2017]

As recorded HRTFs are based on the physical proportions of each individual, the will obviously "differ greatly from person to person" [Zhang et al, 2017, p2]. Zhang and team further discuss issues related to HRTFs, in which measurements lack a 'recognised standard', resulting in an inconsistent database [ibid, p3].

Although binaural technology provides a method to easily capture and process 3-dimensional audio, it has limitations. It should be pointed out that the very nature of the binaural capture method favours the use of headphones [Manning, 2013, p447], as the recording method deals directly with how sound sources engage with each ear. Consequently, loudspeaker reproduction will inevitably affect the original recording by the acoustic properties of the room they are placed in, where the problem is further compounded by larger listening spaces [ibid.]. Reproducing binaural signals in loudspeakers requires crosstalk cancellation [Roginska et al, 2017].

There are easy methods to capture a Binaural recording, one such method is the Neumann dummy head. The Neuman KU 100 dummy head replicates the anatomical functions of the human head, by placing a microphone in each ear canal, and records 2-channels of all the spatial cues as if the listener were there [Roginska et al, 2017].

Figure 3.6 – Neuman KU 100 dummy head
[Roginska et al, 2017]

However, this technique is limited to a single position because it cannot track head position and movement [Menzies, 1999, p71]. Barnard [2010, p34] explains the limitations of binaural recordings in this method where the binaural soundfield is fixed to a stereo recording, and as such, it is “hardwired, unalterable and inflexible”, which cannot take into account “rotations and repositions”. The dummy head also presents an aesthetic problem for live performances but can easily be used in a recording environment. Other binaural recording methods include the Sennheiser Ambeo VR soundfield microphone (used extensively for this study) and the Ambeo Smart headset. The latter is an in-ear headset, which places microphones in a set of in-ear headphones. As these are attached to the recordist, it allows for binaural audio capture on the move, recording the changing soundfield along with the recordist’s movements. This technology is particularly effective in capturing 360-audio for field-recordings. Other applications could include the ability to record audio from each musician’s position, where audience members with headphones are able to change listening positions by switching their input to the Ambeo headset worn by the musicians.

The soundfield microphone (figure 3.7) is currently the most effective method to capture a binaural recording, and will play a pivotal role in this study. The microphone will be placed in an appropriate static location within the performance space for each project, and will act as a single listening perspective within the room. This method will remain a constant throughout this study to provide some continuity in capturing audio evidence.

The Ambeo microphone records four raw Ambisonics A-format signals, which can then be converted to an Ambisonics B-format using the free Ambeo A-B converter plugin (figure 3.8). This decodes the four raw signals into W, X, Y, Z soundfield channels - W is the sum of all four capsules, whilst X, Y and Z represent, front/back, left/right and up/down respectively [Rumsey, 2012].

Once these signals are converted, the RØDE Soundfield plugin (figure 3.9) allows the listener whilst using headphones to audition the binaural recording using different settings, such as the position of the microphone and type of microphone capsule used; allowing the listener to find the most balanced position before processing the final signal to a stereo file.

Rumsey [2012] explains that binaural audio does not need to use this method to capture spatial cues, because if the HRTFs are known or can be approximated, they can therefore be synthesised. He adds that as these HRTFs as so difficult to measure, “accurate sets of HRTF data for all angles of incidence and elevation” are hard to come by and well-guarded intellectual property [ibid, chapter 3]. HRTFs resolve the problem that occurs from a single dummy head or soundfield microphone capture, because the synthesized data can model the filtering effect of the head and ears [ibid.]. This, along with new head tracking technology, means that the binaural audio received by the listener in a set of headphones, can be made to respond to the listeners position and movement; a method widely used for immersive gaming.

Figure 3.7 – Ambeo VR microphone
[Senhnheiser, 2019]

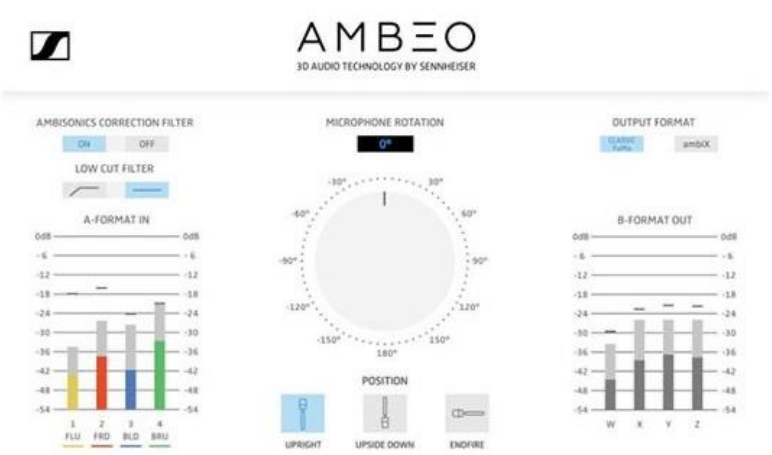


Figure 3.8 – Ambeo A-B converter
[Senhnheiser, 2019]

Figure 3.9 – Soundfield Plugin
[Rode, 2021]

Although the binaural capture method is not new, current listening trends and technological advances in consumer devices (such as mobile phones and headphones), as well as an increased popularity in immersive technologies such as AR and VR technologies, means that binaural listening is growing in relevance [Walton, 2017, p1]. It certainly means that "binaural technology could be considered the most accessible immersive audio, as the majority of people already own the technology required for its playback" [ibid.]. The technology is

increasingly being integrated within virtual reality products [Hall et al, 2017, p173], with "Ambisonics, 3D sound, (…) adaptive rendering, and position-, eye- and head-tracking technologies are all being embraced" [ibid, p163]. The power of these technologies and how creators will innovate, to not only recreate, but to also warp the virtual worlds by tricking our innate spatial perception, is yet to be seen. In addition, the possibilities afforded to creatives by new technologies, will ultimately shape and determine trends and new musical ideas [Barlindhaug, 2019, p23]. A study carried out by Watson [2017, p6], has surprisingly revealed that binaural material produced a lower "overall listening experience" (OLE) than stereo material. Does that mean that the binaural medium is not as enjoyable as stereo, or is this a matter of conditioning and a lack of consumer experience with this new medium?

3.4 - Surround Sound Systems

The development of loudspeakers and more pertinently, large loudspeaker arrays, has hugely influenced the reproduction of music in a given performance environment, and has therefore allowed composers to experiment with the technologies available to them. Although the stereo model remains the prominent commercial format, other formats such as quadrophonic, 5.1 channel surround sound, octaphonic, and even larger loudspeaker orchestras have established themselves in performance and sound reproduction.

Quadraphonic has been largely unsuccessful where the 90° angle creates instability in the perceived image [Malham, 1998, p4]. 5.1-channel surround had established itself as a serious contender, especially in cinema, but it has not fared well in the field of spatial music, where rich spatial material cannot be accurately diffused to create a 360° image [Dow, 2005, p3]. The octaphonic loudspeaker array however, expressed by Jonty Harrison as the 'main eight' [Stansbie, 2013, p48] is the most common configuration, where evenly spaced speakers at 45°, placed uniformly around the audience creates a higher quality spatial image [Dow, 2005, p4]. In Sound Diffusion and Ambisonics, to accurately create a full 360° sound-field and fully envelop the listener, a higher number of loudspeakers needs to be deployed [Stansbie, 2013, p51]. These formats provide the composer with more scope to "realise spatial detail and differentiation" [Dow, 2005, p1].

4, 6 & 8 channel systems

Although stereophonic 2-speaker systems can produce spatial attributes, they cannot create 3-dimentional listening environments [Kyriakakis, 1998, p942]. Quadraphonic systems which contain "four loudspeakers positioned equidistantly and symmetrically at the four corner points of the listening space" were adopted in the early 70s, and developed as a potential system to support spatial audio [Bates, 2009, p35]. The aim was to extend the 2-dimentional field by panning sounds across four speakers [Elen, 2001, p1]. Quadraphonic setups were used in the very early stages of spatial music such as *Kontakte* by Stockhausen. However, research has shown that the 90˚ angle between speakers (or 45° for the listener) does not produce a reliable image [Bates et al, 2007, p.2], "degrading the stereo image significantly" [Bates, 2009, p36] where anything above 60° creates a sound image with a hole in the middle [Elen, 2001, p1]. Sound images were reproduced fairly accurately in front and behind but not to the sides [Kyriakakis, 1998, p943]. Additionally, due to the study of surround sound systems still in its infancy at the time, the psychoacoustics of four-channel sound were not well understood, and therefore productions were badly executed [Ainlay et al, 2004, p12].

Bates concludes [2009, p.70] from evidence Theile provided in the journal *'Localization of lateral phantom sources'* (1976), that a 6-speaker hexagonal array with the minimum 60˚ separation angle is required for a much more reliable image. Many composers, such as Enda Bates, Natasha Barrett and Stockhausen (in his later works) have adopted 8-speaker arrays in some of their work, as it reduces the angle between each speaker. The octaphonic/8-speaker system is realistic in resource terms, where more loudspeakers the better the balance of the imaging [Malham, 1998], and it can also be employed with Higher Order Ambisonics [Bates, 2009, p.iv]. The popularity of the octaphonic system stems in its availability, with 8-speakers spaced at 45° intervals and readily available soundcards and software applications to process spatialisation [Dow, 2004, p4]. However, matching speakers (same manufacturer and model) are necessary to produce accurate sonic imaging through the distribution of equal volume, whilst the physical location of the speakers is also imperative [Barrett, 2002, p.321]. There

are a variety of ways to setup the 8-speakers, composers may wish to plan for this during the creative process and include instructions in their program notes [Dow, 2004].

Ableton Live contains a surround sound panner used for Project 3 (chapter 10), and allows for three different settings – *Room*, *Circle* and *Centre*. *Room* uses stereo pairs placed clockwise and anti-clockwise from the centre position, beginning with the first two speakers' setup as a standard stereo pair from the centre (figure 3.10). *Circle* uses the same setup with regard to speaker position, but the stereo pairs are setup up sequentially around the centre in a clockwise rotation (figure 3.11). The final *Centre* setup positions speaker 1 directly in front of the *Centre*, and then continues in the same clockwise rotation at 45° intervals (figure 3.12). Regardless of how it is setup, the key objective of the octaphonic system is to permit smooth transitions of sound sources across the sound space to fully envelop the listener [ibid., p4].

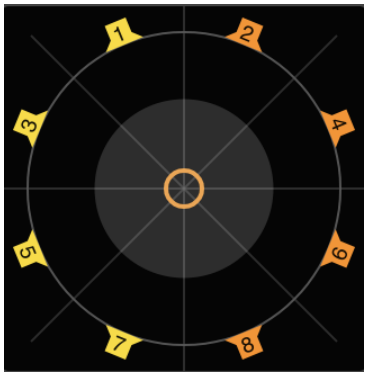


Figure 3.10 – Room

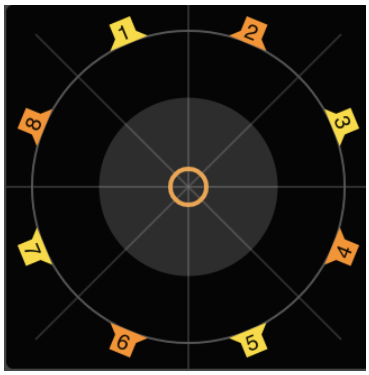


Figure 3.11 – Circle

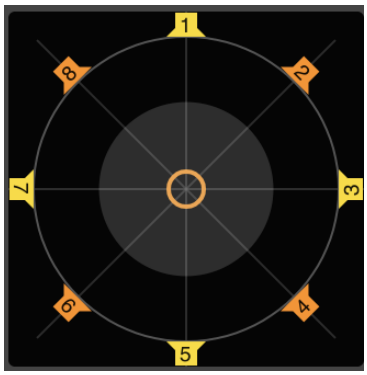


Figure 3.12 – Centre

Dow however would argue that the octaphonic system is not sufficient for diffusion works with rich spatial characteristics [ibid.] Larger speaker arrays enhance the listeners ability to detect the localisation of audio signals because the signals can be spatially separated [Bates, 2009, p.iv], and therefore helps listeners clarify complex content, especially pitch and timbre [Harley, 1998, p.150].

5.1 + 7.1, 10.2 & 22.2 systems

Disney pictures conceived a surround-sound system for their upcoming 'Fantasia' film in 1938, called 'Fantasound'; remarkably, this bares resemblance to the 5.1 system used widely

in cinemas much later, which incorporated a 5-channel system, with three speakers at the front and two at the rear [Ibid].

> *"In the process of recording the film's soundtrack, those same engineers also — astonishingly — invented panning, multitrack recording, and overdubbing!"* [ibid.]

The 5.1 system is one of the most successful and long-lasting surround-sound systems, commonly used in cinemas and home theatre systems. It is comprised of three front channels (left, centre and right), with the addition of 2 rear channels and an LFE subwoofer (figure 3.13). The LFE only carries low frequency content, and as this is approximately one-tenth of the full bandwidth, it fittingly receives the .1 in 5.1 [Ibid.].

> *"This was seen by researchers as being the minimum number of speakers required to provide an immersive, enveloping experience for the listener, while still providing a sufficient degree of localization"* [Ibid.]

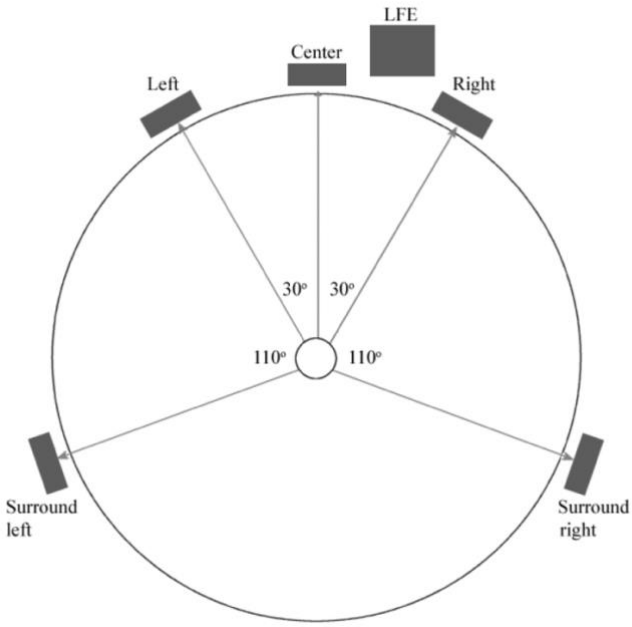


Figure 3.13 – 5.1 surround
[Bates, 2009, p37]

Bates [ibid, p38] explains that although the 5.1 system has been successfully implemented in frontal image reproduction, it is less suited to spatial music because of problems with the lateral and rear images. At the front, the traditional equilateral pair is supported by a centre

channel for greater image accuracy, however, the 140° angle at the rear creates a broader and less stable image, which would explain why the rear channels are usually used for more ambient sounds [Catalano, 2011]. As Dow explains, the image will be at its best in the front, poor at the back, and variable at the sides, whilst he argues that the LFE channel is not required for acousmatic works if the speakers used are full bandwidth [2004, p3].

> *"Essentially the front three channels are intended to be used for a conventional three-channel stereo sound image, while the rear/side channels are only intended for generating supporting ambience, effects or 'room impression'. In this sense, the standard does not directly support the concept of 360° image localisation, …(whilst) the loudspeaker layout is not suited to it"*
>
> [Rumsey, 2021, chapter 4]

Other surround- sound systems include the 7.1, which simply adds two more channels at the centre-left (CL) and centre-right (CR) positions, and was primarily designed to supplement the sound image for all seating positions in a cinema [Rumsey, 2012]. The 10.2 system designed by Tomlinson Holman attempted to incorporate sound imaging on the vertical plane, by adding two height channels at the Front Left and Front Right [Roginska et al, 2017]. An additional Centre-Rear channel was installed to reduce the 'hole' at the back from the original standard 5.1 model, and a 2nd LFE channel, one on each side for greater lateral separation [ibid.]. A 22.2 system goes further in adding height to create a fully enveloping sound space. There are 10 middle layer channels, with 5 at the front for a strong frontal image, 9 upper layer channels with a centre channel facing downwards, and 5 lower layer channels, that includes the two sub-channels (figure 3.14) [Hamasaki et al, 2004].

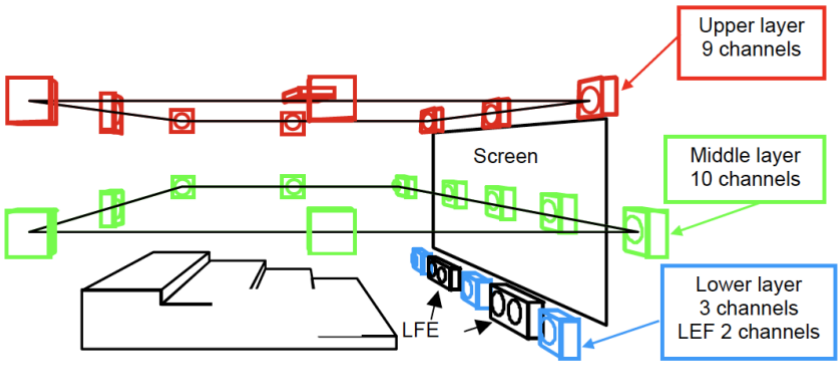


Figure 3.14 – 22.2 surround sound
[Hamasaki et al, 2004, p382]

Figure 3.15, highlights the level of immersivity in relation to the playback format on a scale between 0 to 100, demonstrating that the larger loudspeaker arrays are far more adept to producing a 3D audio experience.

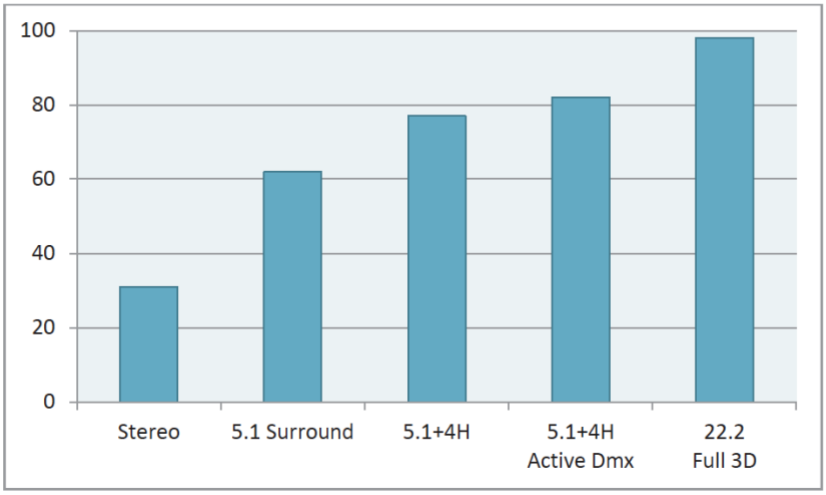


Figure 3.15 - Immersivity Level
[Meltzer et al, 2014, p6]

Many of the surround sound systems explored in this chapter have been specifically designed with the cinematic experience in mind, and therefore do not always translate effectively to music performance, such as spatial and immersive music practices.

Sound Diffusion Systems

Hence, there is a trend as Natasha Barrett [2016, p35] explains for more Permanent High Density Speaker Array's (P-HDLA), such as the IEM-Cube at the Institute of Electronic Music and Acoustics that features a 24-speaker array; the *Motion Lab* at Oslo University featuring a 47-speaker array; the highly influential *Espace De Projection* by IRCAM that features 75-speakers [Barrett, 2016, p36]; the Acousmonium in Paris; and the BEAST system at Birmingham University, founded by Jonty Harrison in 1982 that can boast up to 100 speakers within the concert space [BEAST, 2020]. Both the Acousmonium and the BEAST systems are flexibly configurable and frequently taken on tour [Zvonar, 2005, p12].

> *"The BEAST system uses up to thirty channels of loudspeakers, separately amplified and arranged in pairs, each pair having characteristics which make them appropriate for a particular position or function. They include custom built trees of high frequency speakers suspended over the audience, as well as ultra-low frequency speakers."* [Harrison, 1998, p122]

Barrett [2016, p35] explains that a P-HDLA, usually employs similar loudspeakers, permanently setup in either a hemisphere or cuboid, distributed evenly around the space. The permanent setup eliminates arduous and time-consuming processes, whilst providing formats that can accommodate most commercial and non-commercial needs [Ibid.].

These complex loudspeaker systems have afforded the Ambisonics and Sound-Diffusion composer the tools to create complex immersive environments, delivered effectively to all audience members. Stansbie explains how these environments can be created with HDLA:

> *"by presenting sound materials over a single stereo pair of loudspeakers, the diffuser is (potentially) able create an impression of: intimacy (often by using a stereo pair that is close to the audience, perhaps with a narrow stereo image), immensity (in cases where loudspeakers are located further away and perhaps placed some distance apart), elevation (in cases where loudspeakers are located above the audience), distance (when speakers are located at a physical distance from the audience, sometimes pointing away from the audience or pointing at a wall), surprise (particularly when the stereo image is placed behind the audience), and so on."* [Stansbie, 2013, p51]

Acousmonium

There are many systems that employ large loudspeaker arrays, one of the earliest and most significant is the Acousmonium. It was located at the *Maison de Radio France* in Paris, devised by François Bayle and Jean-Claude Lallemand as part of the *Groupe de Recherches Musicales* (GRM) [Mooney, 2005, p219]. Its first performance, which took place in Paris in 1974, featured Bayle's *Experience Acoustique* [Bates, 2009, p150]. This is an early example of a Sound Diffusion system and gave rise to the term 'loudspeaker orchestra' [ibid., p199]. The system employed a large number of loudspeakers that could be arranged in a different size and shape. One such design used *Main*, *Wide*, *Distant* and *Rear* speakers, with the audience and diffuser placed at the centre (figure 3.16) [ibid, p151].

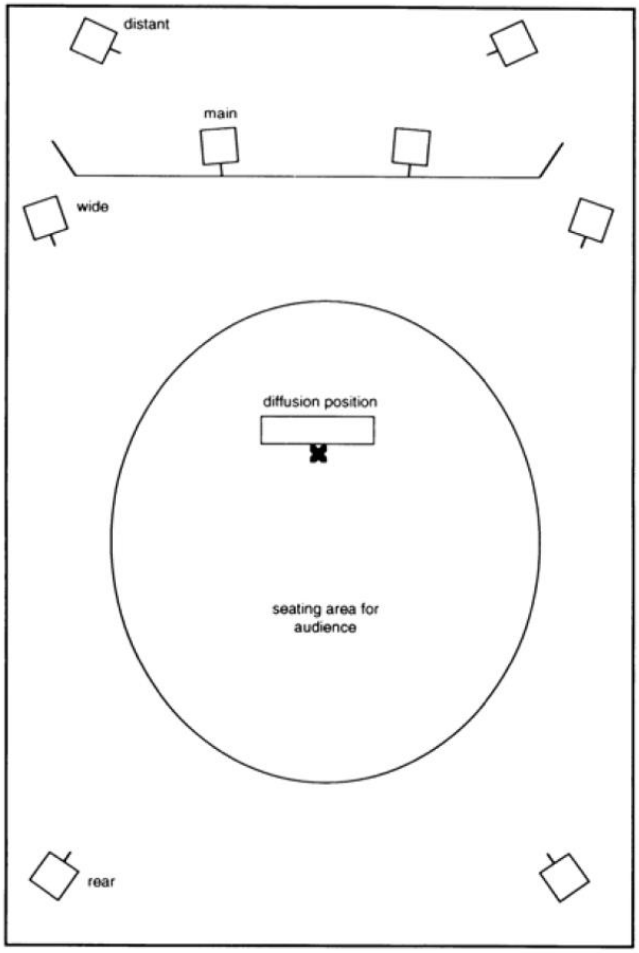


Figure 3.16 - Acousmonium Speaker Setup
[Bates, 2009, p151]

BEAST

The BEAST system (Birmingham Electro-Acoustic Sound Theatre) was founded in 1982 by Jonty Harrison at the University of Birmingham. It is specifically designed for the performance of electroacoustic music, consisting of over 100 speaker channels using various arrangements around and suspended above the audience (inclined towards the centre), which a performer can control using a diffusion console [Mooney, 2005, p207]. The system is built around what Jonty Harrison called the '*main eight*' (figure 3.17), comprising of a horizontal surround system of 8-speakers which he described as the absolute minimum requirement needed in stereo playback for tape [Bates, 2009, p152]. This octaphonic system is replicated at different positions – *close*, *floor*, *higher*, *gallery* and *ceiling* [ibid.]. There is also a vertical *ferris-wheel* version around the audience pointing inwards, as well as vertical 'rose' array at a distant wall [ibid.].

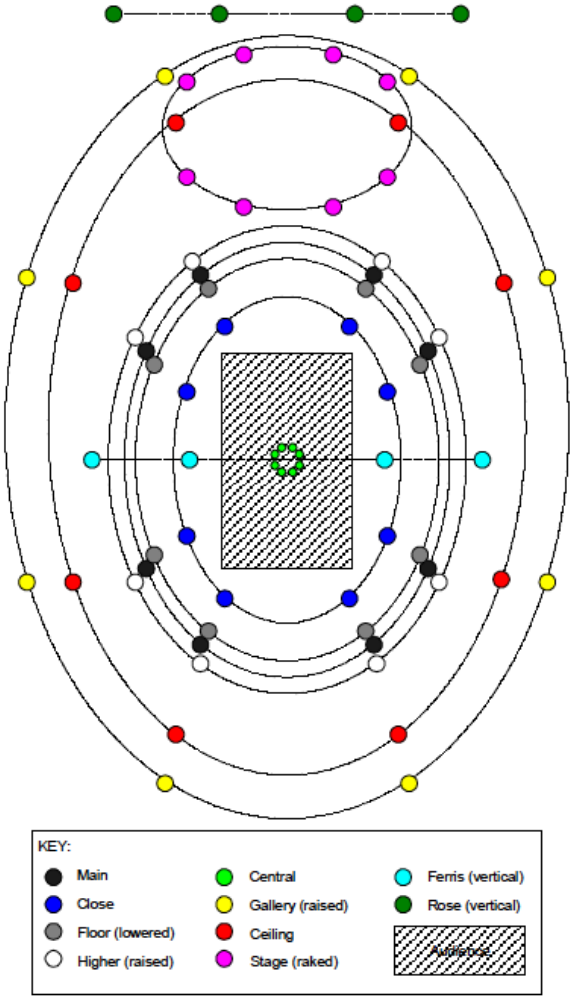


Figure 3.17 - BEAST
[Mooney, 2005, p208]

Beyond the '*main eight*' configuration, the next most significant additions to the system are the subs and tweeters, the later suspended over the audience as ten *stars* (figure 3.18) [Harrison, 1999, p4]. The BEAST system has been designed to provide some configuration variations depending on the hall, some additions include:

Side Fills – Long and thin halls

Stage Centre speakers – Wide halls, for resolving 'hole in the middle' effects

Front/Back – stereo pair, positioned centrally high on the stage, for resolving 'hole in the middle' effects

Punch speakers – central and outward pointing for impact

Front & Rear Roof speakers – for height where possible

Proscenium speakers – for height at the frontal image

Very Distant – speakers facing away from the audience to enhance the length of a short hall

Further detail can be found in Harrisons [1999] '*Diffusion: theories and practices, with particular reference to the BEAST system'.*

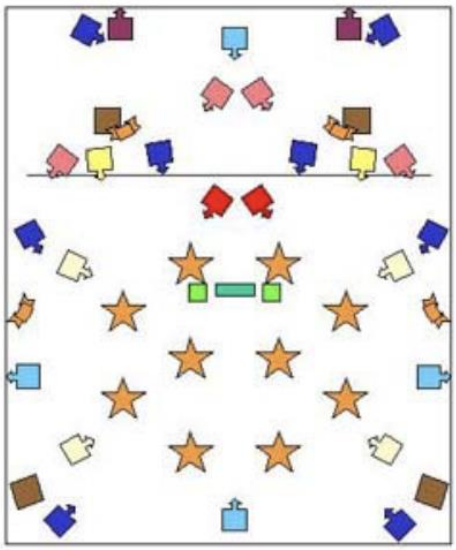


Figure 3.18 – BEAST
[Harrison, 1999, p4]

Creatophone

At the *Centre for Research in Electronic Art Technology* (CREATE) in Santa Barbara California exists the Creatophone project, which consists of 16 pairs of loudspeakers [Mooney, 2005, p211]. It is a spatial projection system that has been specifically designed for flexible configuration, with the aim to enhance "the listening experience, regardless of seating", due to the clarity and power of the system [Harley, 2000, p67].

> *"The various inputs (ADAT, DAT, CD, computer with 8-channel output) were fed into a 16-bus Soundcraft mixer and then out through four Threshold stereo power amplifiers via Horizon, AudioQuest, and Tara interconnects and MIT and AudioQuest speaker cables to eight B&W Matrix 801 loudspeakers. The room, a rectangular lecture/recital hall wider from side to side, has tiered seating curved in a semi-circle around the small stage area. The loudspeakers were placed in a standard octagonal configuration with two in front, two in rear, and two each on either side. The best listening was found in the centre, as one would expect, but many spatialized effects could be heard quite effectively from other locations as well."* [ibid.]

Cybernéphone (formerly the Gmebaphone)

Christian Clozier who created the Cybernephone (Figure 3.19) was quick to clarify its differences from the Acousmonium and for it not to be considered as a 'loudspeaker orchestra', mainly due to the frequency splitting device it uses called the *Gmebahertz* [Stansbie, 2013, p159]. The Cybernephone utilises this technique to spatialise the work across (up to 50) loudspeakers with different frequency responses which can be flexibly configured [ibid.]. Additionally, the system incorporates a 'computer-assisted' diffusion mode that enables complex and specific spatial characteristics to be performed in real-time or pre-recorded [ibid.]. The Cybernephone was developed at the *Insitut de Musique Electroacoustique de Bourges* (IMED) from 1973 and was called the Gmebaphone up to 1997

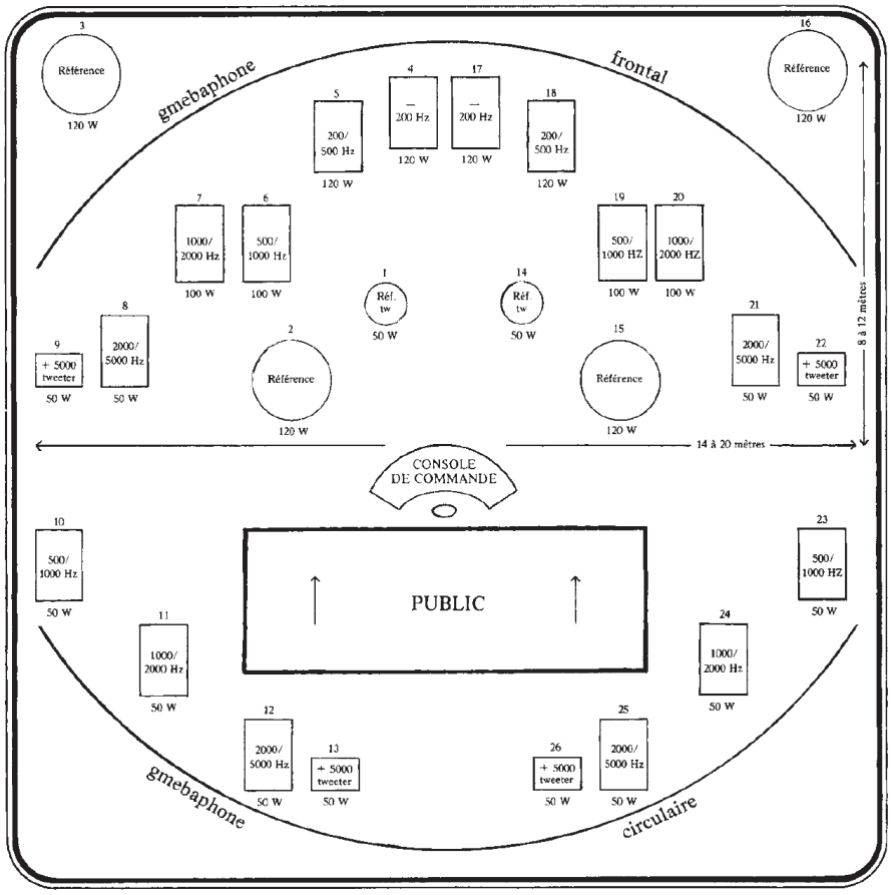


Figure 3.19 – Gmebaphone configuration, late 70s
[Emmerson, 2017, p153]

Many of the systems discussed thus far have been developed in the name of research and experimentation. To this day, very few commercial multi-channels immersive systems exist. It is therefore worth noting *Envelop*, a San Francisco based non-profit organisation steeped

in the values of immersive and spatial audio, which includes a 32-speaker venue utilised for immersive performances, wellness and education, as well as a transportable octaphonic system. The addition of the in-house audio software tools developed for Ableton Live Suite called *Envelop for Live*, enables sound sources to be placed anywhere in the room with interactive lights for synchronised audio-visual events. Systems such as these exist across the globe, but they remain limited in their numbers and commercial use.

2.5 - Ambisonics

Engineers and technologists have for a long time worked towards reproducing recorded sources with realism and spaciousness [Ortolani, 2015, p1]. Ambisonics is a technique that uses complex multichannel systems to reproduce a soundfield (the capture of three-dimensional audio), in which sound sources appear unchanged against a listener's position and head movement [Menzies, 1999, p67]. It is a technique first introduced in the 1970s by Michael Gerzon, which allows spatial audio information to be recorded and stored, so that it can be accurately reproduced as a 3D soundfield [McKenzie et al, 2017, p1].

Ambisonics is not the same as a traditional surround system because it also contains information on the vertical plain (in addition to the horizontal), therefore providing height as well as depth and width [Ortolani, 2015, p3]. Ambisonics technique produces an optimum listening position, a 'sweet-spot' that is much wider and more robust [ibid, p4], meaning more of the audience is enveloped in a sonic experience that is not compromised by their position and movement. Ambisonics can also be used in the reproduction of spatial music through large loudspeaker arrays, allowing the composer to choose the number of speakers based on their intentions; therefore proving a flexible format which does "not specify a particular loudspeaker array, neither in terms of quantity nor placement" [Henriksen, 2002, p.88]. Ambrose Field explains that the Ambisonics format not only provides flexibility, but also portability and consistency, where the spatial characteristics of the work created in the studio will easily translate in different environments using different loudspeaker systems [Austin, 2001, p23]. The Ambisonics format therefore has a varied and flexible use, not only in

electroacoustic and environmental music, but also for immersive theatre and sound installations.

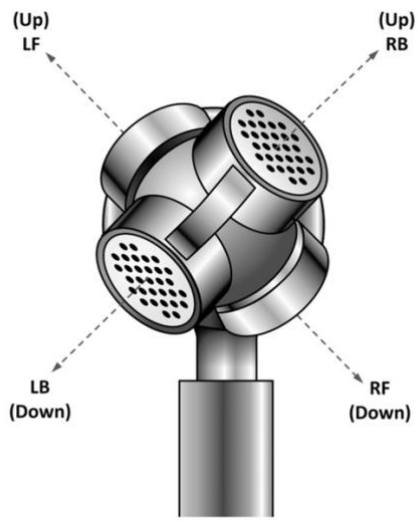
> *"Now with ambisonics I can know that my spatial information is going to be intact in all those situations, and I can know that the public will get what I wanted as a composer, and it can run 24 hours a day."*
>
> Ambrose Field in an interview with Larry Austin [Austin, 2001, p24]

To understand Ambisonics we must first explain the term *soundfield,* which means "the capture, reproduction and description of sound waves", whereas the objective of "binaural, stereo and surround sound systems … is to create perceived objects and auditory events" [Roginska et al, 2017, Ch4]. The aim of Ambisonics as Gerzon intended was to provide an alternative technology to channel-based stereo, and achieve full 360° spherical directionality [ibid.]. In addition, it can be applied to "mono, stereo, horizontal surround-sound or full 'periphonic" reproduction including height" [Rumsey, 2012, Ch4]. *Periphony* is Greek for 'sound around the edge', and is a term commonly used to explain the use of speakers to produce sound from all directions [Elen, 2001, p1].

The soundfield tetrahedral microphone allows the capture of a 3D soundfield in Ambisonics A-format. This is comprised of left-front (LF), right-front (RF), left-back (LB) and right-back (RB) as indicated by figure 3.20 [ibid.]. The B-format signals, W, X, W & Z (figure 3.21) are derived from the A-format microphone as [ibid.]:

- W channel – omnidirectional polar pattern
- X, Y and Z channels – three figure-of-eight polar patterns that represent width, depth and height

These four channels represented by the Soundfield microphone can capture First Order Ambisonics (FOA) [McKenzie et al, 2017, p1]. The four channels can then be easily decoded into B-format using software to allow greater control of the soundfield, such as rotation [ibid.]. There are several Ambisonics formats to meet different needs, with A and B the most popular due to accessibility.



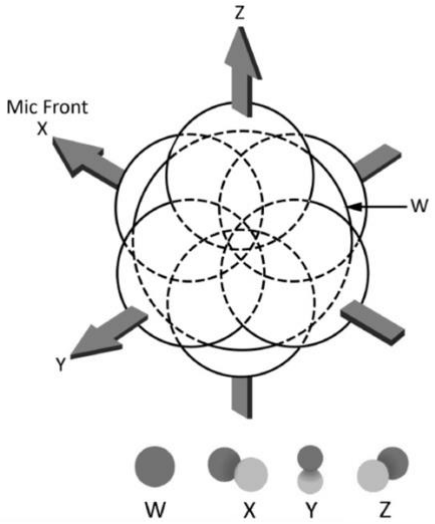


Figure 3.20 – tetrahedral microphone. Figure 3.21 – illustration of W, X, Y and Z [Roginska et al, 2017, Ch4]

"A-Format: suitable for miking with specific microphone (e.g. Soundfield mic);
B-Format: suitable for miking and processing with studio equipment;
C-Format/UHJ: suitable for mono, stereo, 3-channel systems and broadcasting;
D-Format: suitable for decoding and playback through array of speakers;
G-Format: like D, but decoder is not required;"

[Ortolani, 2015, p13]

Higher Order Ambisonics (HOA), second, third, fourth etc. provide an even further flexible approach of representing a 3D soundfield [Moreau et al, 2006, p1], which is encoded onto spherical harmonics (figure 3.22).

> *"Spherical Harmonics are spatial functions, which allow one to represent any sound wave as a linear sum of directional components"*
>
> [Roginska et al, 2017, Ch4]

The larger the listening area, the larger number of spherical harmonics are required [Barrett, 2010, p4]. Therefore, for a greater quality of spatial resolution within a given space, the more spherical harmonics are needed for the material to be captured or synthesized in Higher Order Ambisonics [Ibid.]. Once the signals are encoded with HOA spherical harmonics, they can be decoded to convert these signals for loudspeaker reproduction.

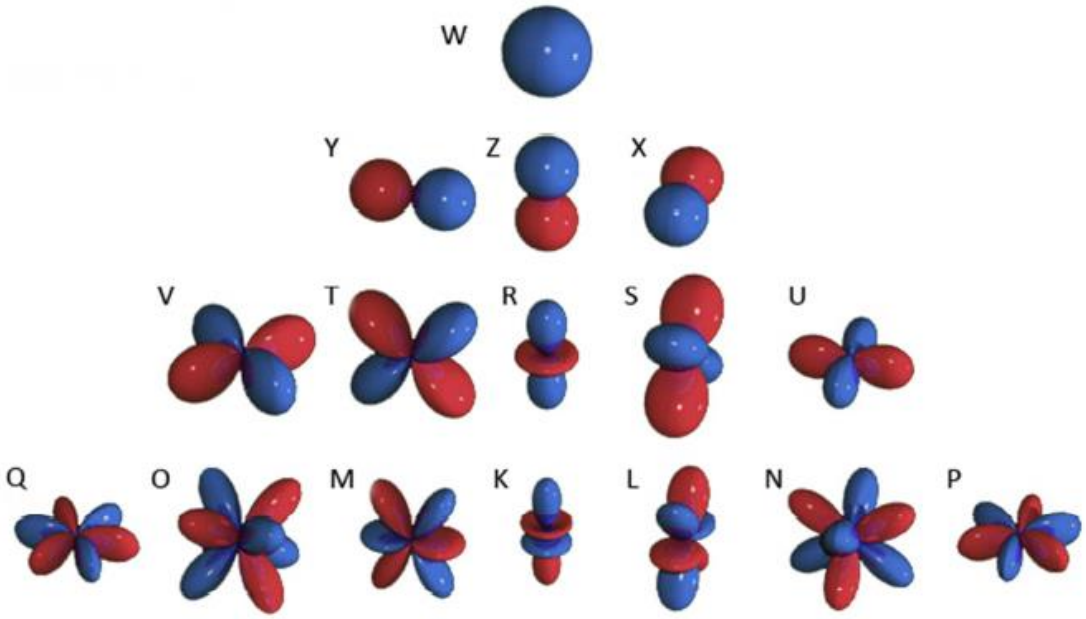


Figure 3.22 – Spherical Harmonics for HOA, (W, X, Y, Z are FOA)
[Ortolani, 2015, p9]

Natasha Barrett uses HOA in her works as it allows for greater control of the spatial music structure [Otondo, 2007, p.13]. Quackenbush explains that "first-order ambisonics provides limited spatial resolution, [but] higher orders provide increasingly higher resolution and better approximation of the original soundfield" [2021, p1580]. HOA requires a larger number of speakers to accurately represent the soundfield, whilst the speaker layout and types will affect the timbral characteristics of the original capture, making the Ambisonics soundfield distinguishable from natural ones [McKenzie et al, 2017, p2]. HOA like object-based audio (chapter 3.6) is agnostic of loudspeaker layout and requires a renderer for the content to be reproduced to the target listening system, including headphones [Quackenbush, 2021, p1580]. This is because ambisonics signals "are not related to speaker position but instead describe a sound source's direction by means of their relative amplitudes and polarities" [Bleidt et al, 2015, p7].

The *Eigenmike®* is currently one of the few options available to record HOA up to 4th order [Roginska et al, 2017, Ch4].

Ambisonics microphones [Bertet et al, 2013, p8]:

- 1st order - Soundfield microphone
- 2nd order - 12-sensor microphone
- 3rd order - 8-sensor microphone
- 4th order - 32-sensor microphone

Figure 3.23 - *Eigenmike®* 32-sensor microphone [Roginska et al, 2017, Ch4]

Beyond the fairly easily accessible Soundfield microphone which allows for A and B format reproduction at FOA, composers that intend to use 2nd order or above (with more spatial quality), tend to synthesise signals from either artificial sounds or stereo recordings [Dow, 2005, p5]. The loudspeaker reproduction system does not need to be considered during the recording or synthesis of the soundfield [Malham, 1995, p62], however a minimum of eight identical loudspeakers that are appropriately located in the space are required for 3rd order Ambisonics [Barrett, 2010, p4]. Furthermore, if the full 3D environment is to be reproduced, which includes spatial elements with height on the vertical plain, then speakers are required above and below the audience (periphonic) [Dow, 2005, p4]. Rumsey explains that the more loudspeakers available the larger the sweet-spot becomes [2020, p391].

This highly technical and resource hungry reproduction method of a soundfield does have many positives however. As Larry Austin comments, Ambisonics allows the composer to create imaginary spaces, be it from real or artificial soundscapes [Austin, 2001, p25]. For example, the listener could be transported from a large to a tiny space within a minute [Ibid., p26]. Stansbie [2013, p52] describes the types of techniques a sound diffuser can use within an Ambisonics performance:

- Longitudinal movements (front to back, or vice versa),
- Lateral movements (side-to-side),
- Diagonal movements (sounds traverse the listening space from one point to another),
- Circular movements (sounds move around or across the audience),
- Vertical movements (up and down)
- Combinations of

Ambisonics may currently be the most established and powerful method for sound spatialization and reproduction of a 3D audio environment using loudspeakers [Malham et al, 1995, p58]. The Ambisonics sound system allows the composer to encode sound directions so that listeners can be fully immersed by the sound in a 3-dimensional space [Ibid., p62].

It is not a system that many audiences are aware of or are experienced listening to let alone accustomed to its unique method of delivering a full 3D soundfield. It therefore takes audiences some time to get accustomed to its audio qualities, and in some cases, can be quite disconcerting to some listeners [Austin, 2001, p23]. Ambrose Field explains that you can move and rotate the entire space, you can "make the listener feel that one minute they're in a large open area, and the next minute they're shut in a closet" [ibid, p26]. He adds that "you can even walk outside of the Ambisonics array and still perceive spatialization" [ibid, p24]. He clarifies that, in Ambisonics, "where the speakers actually are has absolutely nothing to do with where the sound is coming from" [ibid, p27], and therefore questions, ''How can we get the sounds to move out of the speakers?'' [Ibid., p23].

As the Ambisonics method makes many spatialisation techniques easy, such as moving sounds around, potentially in a clichéd manner, Field stresses that the composer must question why particular techniques are being used within the performance [Austin, 2001, p26]. Although the capture, synthesis and process required in Ambisonics may seem demanding, it is unsurprising that the flexibility and versatility of the format afforded to composers, means that for many, including Field, Austin and Barrett, it is a method which provides the creator with unimaginable scope, whilst its ability to retain the spatial qualities produced in the studio in any space, is highly advantageous [Ibid., p23].

This technique has become more popular in recent years due to the development of software plugins such as *SPAT Revolution* by IRCAM, *B360* by Waves, and other more affordable spatialisation plugins, including a range by dearVR, some of which allow for the encoding and decoding of audio content whether accurately captured in Ambisonics format or not (in mono, stereo, surround), to be mixed in 360˚ for headphones. The commercial use of headphones, mobile devices and gaming in everyday life, as well the growing commercial viability of VR projects, have all contributed to the increased use of Ambisonics B-format.

3.6 - Object-Based Audio

Many of the technologies discussed thus far have demonstrated the industry's continuing evolution in its attempt to create a listening paradigm that involves the full 3D soundfield. This 'immersive 3D audio' paradigm is what Neuendorf and team call a "hot topic" [2014, p52], with evident progress being made for both loudspeaker and binaural headphone reproduction (as highlighted above). Quackenbush describes 'immersive audio' as an auditory experience in which the listener is fully immersed in a sound scene – namely, the collection of audio events [2021, p1578]. Since the development of stereophony, which is capable of creating an auditory illusion through phantom imaging [Quackenbush, 2021, p1578], the implementation of additional speakers on the horizontal plane in setups such as 5.1 and 7.1, have enabled sound reproduction systems to increase envelopment on the horizontal plane, by adding sound on the extreme left and right as well as behind - thereby enhancing the surround sound image [ibid.]. The addition of height speakers have permitted music and sound with elevation, with such systems being used successfully in movie theatres to create the "sensation of full listener immersion" [ibid.].

> *"These sounds emanating above the horizontal listening plane offer important auditory cues that are missing from today's stereo, 5.1, and 7.1 speaker configurations. it becomes interesting to follow action vertically as well as horizontally and to provide realistic auditory presentation for sources in motion on or off the screen."* [Bleidt et al, 2015, p5]

Many of these public and home surround sound systems are based around the traditional idea of channels. Channel-based audio delivers specified signals to a desired number of

loudspeakers. A disadvantage of channel-based audio is that it requires the content to be reproduced on an identical system as the one it was generated on, unless time consuming conversion is applied [Quackenbush, 2021, p1579]. For example, if a producer has just mixed sound and music for a 7.1 system, the mix requires a 7.1 system for it to be accurately presented.

The manner in which we now consume sound and music is so varied (ranging from mobile phones, laptops, home hi-fi's, soundbars and headphones, to complex cinema systems) that the channel-based audio platform is problematic when trying to reproduce immersive audio. Furthermore, as Bleidt and team explain, from the consumer's perspective, audio should fit their "individual listening condition irrespective of the origin and distribution channel of the content" [Bleidt et al, 2015, p8].

The *object-based audio* approach has demonstrated many advantages, looking to be, not only a solution to this spatial audio problem, but potentially the future of consumer listening due to versatility. "Object-Based Audio (OBA), … is a broad term that refers to the production and delivery of sound based on audio objects" [Simon et al, 2019, p3]. Leading audio companies have been competing in this field, with many 3D audio technologies already in circulation, such as Dolby Atmos, DTS-X, Auro 3D and Sony 360 Reality Audio to name a few - some of which use the MPEG-H audio codec [Zhang et al, 2017, p1].

To this day, the majority of spatial cues use conventional channel-based techniques, such as panning to deliver spatial characteristics between instruments, voices and sound effects [Herre et al, 2015, p771]. Object-based audio as Herrer and team explain [2015, p771], is "agnostic of actual reproduction loudspeakers setup" as the coded information renders the sound-objects position for custom playback, and therefore breaks the bond between the production method and the reproduction setup. This is an advantage that object-based audio has over channel-based audio [Quackenbush, 2021, p1579]. Audio objects in the production stage are coded with metadata that describe their position in the 3D soundfield and any time-specific position trajectories [Coleman et al, 2018, p1919]. A collection of such audio objects with their metadata create a virtual sound scene, which can be rendered by the end user for playback on an outgoing reproduction system - loudspeakers or headphones [Quackenbush,

2021, p1579]. The key aspect of this technology is that the renderer translates the audio scene for the best possible listening experience on the available monitoring system [Coleman et al, 2018, p1919]. Simply put, object-based audio technologies allow content creators to place a collection of sounds within a soundfield that can be accurately reproduced for headphones, soundbars, cinemas and even cars, making immersive sound a consumer-friendly product.

Figure 3.24 illustrates the differences between channel and object-based audio. In the channel-based process, it is clear that for the content to be presented in the best possible quality, the creator must produce content with "knowledge of the target reproduction system" [ibid, p1921]. Whereas in object-based audio the renderer is not acting on the actual audio, but on the metadata that provides various information on the audio-object [Coleman et al, 2018, p1924].

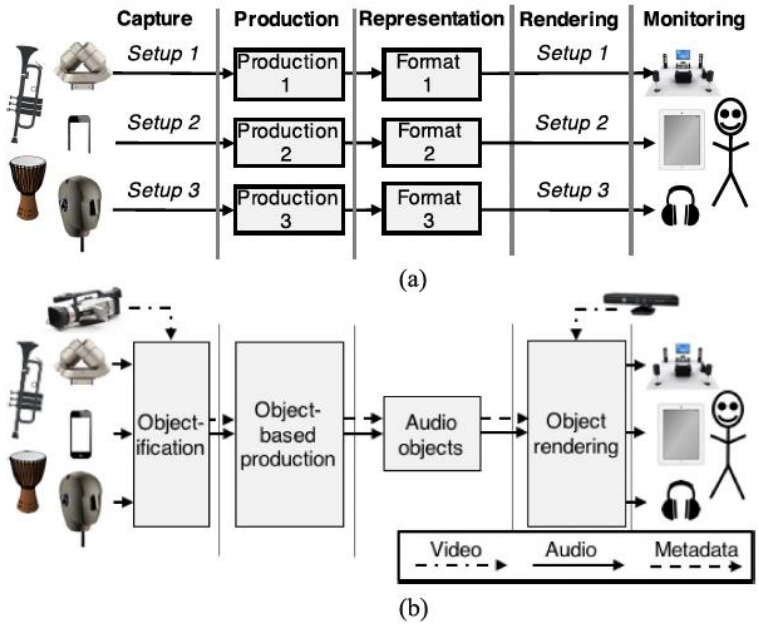


Figure 3.24 - [Coleman et al, 2018, p1920]

Thus far, only the advantages of object-based audio for immersive sound on various listening conditions have been discussed. However, this paradigm has another significant advantage to channel-based audio due to the use of metadata, which can provide further flexibility and personalisation to the end-user, based on their preferences [Coleman et al, 2018, p1921]. One such use-case is to allow objects to be adjusted, such as the level of dialogue or

commentary against that of background sound - a useful tool for the hearing impaired [Bleidt et al, 2015, p4].

> *"Tests have shown that an enhancement of the dialogue by about 6dB offers a substantial improvement in intelligibility for an audience with a typical age-related hearing loss"* [Bleidt et al, 2015, p10]

Further controls could be offered to the consumer such as choosing the language, narration for the visually impaired [ibid, p10], or even allowing fans to choose home or away commentary [ibid, p3]. Thus, object-based audio has the additional advantage of allowing broadcasters to provide a range of personalisation features based on their consumers desires [ibid, p11]. Personalisation options can be provided as separate audio-objects, whilst the rest of the fixed content such as music, sound effects and ambience are mixed as a single channel-bed [ibid, p3]. The broadcaster can therefore create user-friendly 'presets' depending on the program, such as various sports presets which allow the user to select a pronounced commentary or more stadium-like ambience [ibid, p4]. This will deliver consumers the opportunity for new and unique "opportunities for immersive, personalized, and interactive listening experiences" [Coleman et al, 2018, p1919].

It is clear to envisage that broadcasts offering personalisation options will require larger bandwidths for successful presentation to the end-user through various mediated means. Therefore, the experience will vary significantly depending on what system and internet connection the consumer uses. Object-based audio production will inherently contain larger files; figure 3.25 demonstrates various bitrate sizes for different reproduction systems.

Bitrates in kb/s for:	Good	Recommended	Transparent
22.2 Channels	256	512	1200
7.1 + 4 Height Channels + 4 Objects	200	384	800
5.1 Channels	96	160	256
2.0 Channels	32	56	160

Figure 3.25 - [Bleidt et al, 2015, p6]
Taken from the paper Spatial Hearing: The Psychophysics of Human Sound Localization

Bitrates are just one potential hurdle in the object-based model. The other is compatibility issues due to the various audio technologies involved, such as Dolby, Auro Technologies and

DTS, all of which require their own production tools and, in some cases, use their own audio codecs. There is also the matter of which DAWs provide native access to object-audio production tools.

> *"To realize the full potential of object-based audio, system components must share common interfaces, covering the end-to-end signal pipeline from recording to listening, … in the production stage the producer is only required to create a single version of the content for all systems."*
>
> [Coleman et al, 2018, p1919]

Dolby Atmos is arguably the leading player in the field, providing a "flexible, object-based 3D audio format" [Bresler, 2021, p3]. The platform aims is to create audio which is realistic and immersive, by replicating the soundfield for various setups, including cars, cinemas, gaming, in the studio, home systems and on the move for binaural listening on headphones [Dolby, 2022]. Dolby Atmos is already widely used by the industry, with many films produced in Atmos for cinema, with over four thousand movie theatres globally already supporting the system [ibid.]. The music industry has also got involved, where both major and independent labels are now producing music of their artists in Dolby-Atmos, including The Weeknd, Billie Eillish and Justin Bieber to name a few [ibid.]. Support for Atmos on Apple Music, Tidal and Amazon Prime, means that immersive audio has been integrated within streaming services for the first time [Bresler, 2021, p1]. This transformation is facilitated by the native support of Dolby Atmos on Nuendo, Pro-Tools and recently Logic Pro, whilst plugins are available for Ableton Live [Dolby, 2022].

Dolby Atmos provides producers and engineers with 128 tracks, the first 10 of which are used as a 7.1.2 bed, with the remaining 118 tracks available as audio objects [ibid.]. It uses audio-objects similarly as already explained, where individual objects can be placed anywhere in the soundfield, coded with metadata on their position with X, Y and Z coordinates [ibid.]. The Dolby Atmos Renderer unpacks the audio and metadata for the end-users defined speaker configuration and monitoring. Bresler analysed the Dolby Atmos mix of Blinding Lights by The Weeknd with positive outcomes, where the possibility of placing sounds in the vertical plane provided enhanced separation of sound sources (figure 3.26) [2021, p15]. Bresler argues that the use of spatialisation techniques in the Atmos mix can "create different possibilities for understanding and interpreting the musical content" [2021, p25].

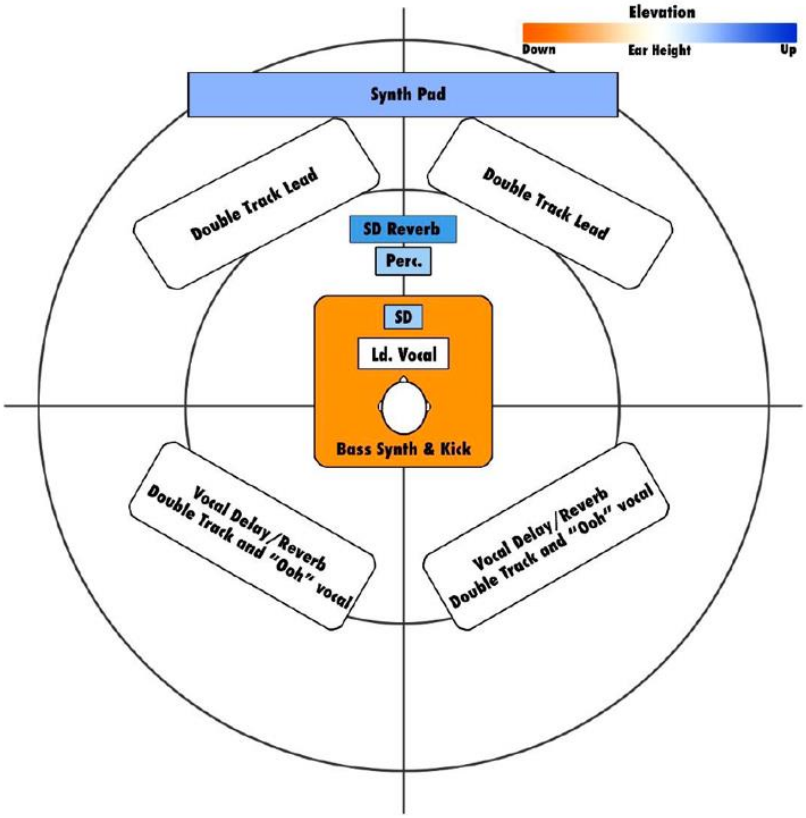


Figure 3.26 – Blinding Lights chorus from Dolby Atmos mix
[Bresler, 2021, p20]

DTS-X which can be considered as the main competitor for Dolby Atmos, was released in 2015 (a few years behind Atmos) with a similar intention of being the leading platform for immersive audio, in particular for cinemas and home theatres [DTS, 2022]. DTS:X is a type of codec based on the company's MDA (Multi- Dimensional Audio) platform which supports both channel and object-based audio production, and therefore end-user personalisation features [ibid.]. Unlike Dolby Atmos which requires a licence fee agreement, MDA is an open-source platform. However, content creators will require DTS-X compatible software applications and DTS-X enabled hardware systems [ibid.]. Although DTS suggests a 7.1.4 loudspeaker system for the best possible immersive sound experience, the platform can render the audio down to any available speaker setup [ibid.].

Auro 3D by Auro Technologies is another competitor for immersive sound production. Auro 3D is based on three height levels as illustrated in figure 3.27 [Auro Technologies, 2022]. Layer 1 acts as the standard 7.1 surround-sound level on the horizontal plane, whereas layer 2

provides 5 height channels on the upper level, with a final optional top layer supplemented by a single speaker overhead (figure 3.28) [ibid.].

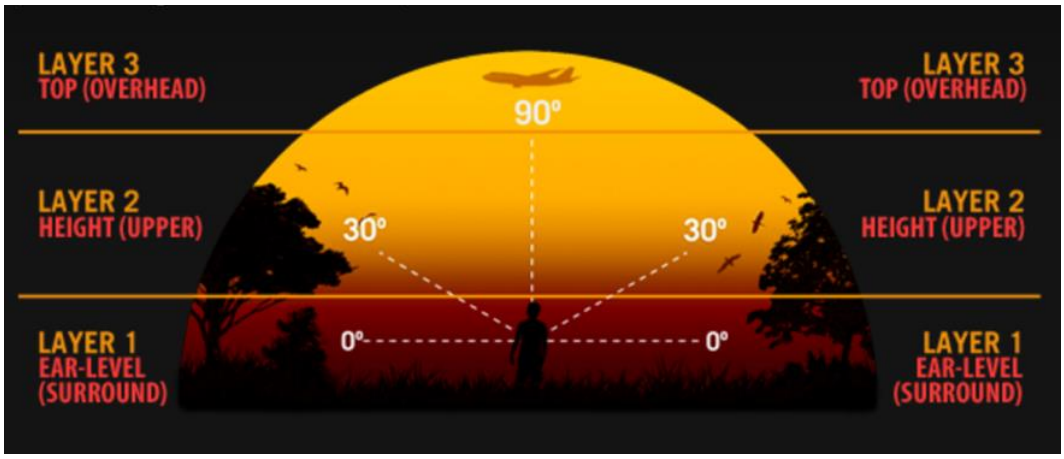


Figure 3.27 – [Auro Technologies, 2022]

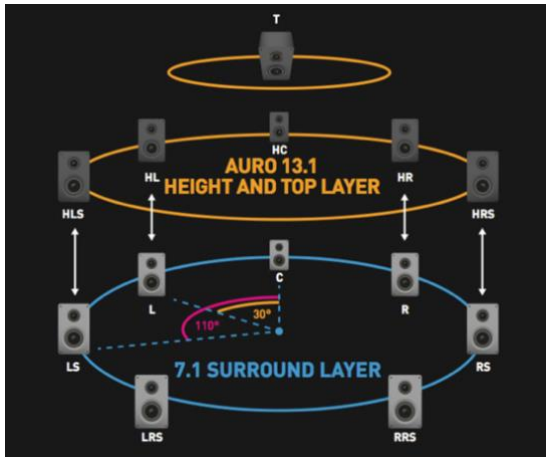


Figure 3.28 – [Auro Technologies, 2022]

Figure 3.29 highlights the effectiveness of different reproduction systems in presenting various sound attributes, with the Auro 3D 9.1 setup (a 5.1 with 4 additional height channels), demonstrating many advantages.

Sony created its own immersive audio platform called *360 Reality Audio*, offering an object-based audio ecosystem based on MPEG-H 3D audio, an “open format standard” [Sony, 2022]. The aim is to empower content creators to produce consumer-ready immersive audio, with more focus on music and streaming platforms on mobile applications [ibid.]. As with other object-based technologies discussed, 360 Reality Audio requires an audio decoder and

renderer. All the technologies summarised require their own tools such as plugins and converters, which can be very costly to professionals. An industry standard would be beneficial, and this is where MPEG-H can play a pivotal role.

ATTRIBUTES OF SOUND REPRODUCTION	2.0 STEREO	5.1 SURROUND	AURO-3D 9.1	WFS*	BINAURAL TECHNIQUES
Front direction	●	●●	●●	●●	●
Surround direction		●	●	●●	●●
Elevation			(●)***		●●
Height			●		●●
Distance/depth	(●)**	●	●●	●●	●●
Proximity to the head				●	●●
Intra-active perspective / [1]				●●	
Spatial impression	(●)**	●	●●	●	●●
Envelopment		●	●●	●	●●
Timbre	●●	●●	●●	●	●●

Figure 3.29 - [Theile et al, 2011, p4]

*MPEG-H (*Motion Picture Experts Group) was standardized in 2015, with a second edition available in 2019 [Quackenbush, 2021, p1579]. It is the next generation of MPEG audio codec offering various advantages [Neuendorf et al, 2014]:

- Personalisation
- Immersion & Realism
- Rendering on all playback devices
- Bit-rate efficiency
- Loudness normalisation
- Audio Objects

With huge developments in high resolution visual playback devices readily available to the consumer in their home and on-the-move, an audio system is required to enhance the video experience [Meltzer et al, 2014, p1], with universal means that supports both broadcasting and streaming applications [ibid, p2]. The MPEG-H 3D audio standard offers the possibility for immersive and personalised audio, improved accessibility through scene-based audio, whilst supporting channel and object-based audio as well as HOA [Herre et al, 2015]. Additional developments include flexible rendering, interactive features and improved loudness control [Neuendorf et al, 2014, p55]; the latter is called “dynamic range control (DRC)” [Bleidt et al, 2015, p9]. The MPEG-H codecs versatility and support for various sound formats, means that

it is receiving a lot of interest from industry [Quackenbush, 2021, p1578]. The rich set of metadata the MPEG-H audio codec provides along with its flexibility, proves to be a versatile production tool for broadcasters, who can configure content for consumer personalisation seamlessly [Fruanhofer, 2022].

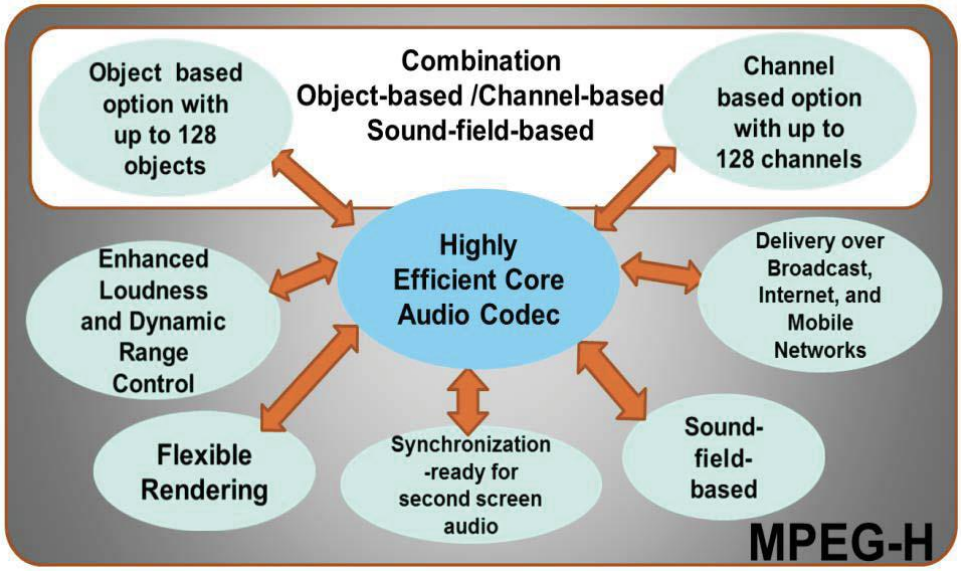


Figure 3.30 – Technology elements of MPEG-H 3D audio standard
[Meltzer et al, 2014, p2]

New technologies already explored have employed elevated and lowered speakers for a greater immersive 3D audio experience, from the 7.1.2 system with two elevated speakers, to 22.2 and even more immersive loudspeaker systems that can truly replicate 3D sound. MPEG-H technology provides high quality audio for all of these surround-sound applications (up to 128 channels or objects), all the way down to mono, stereo and binaural reproduction, entirely independent of the original coding format by bridging the gap between different audio processing methods, therefore eliminating incompatibility [Herre et al, 2015, p770].

> *"In order to allow the reproduction of encoded channel-based content on any available loudspeaker setup connected to the MPEG-H audio decoder, the format converter maps the encoded channel signals to the target speaker layout. As an example, the decoder may detect a 5.1 surround reproduction loudspeaker setup, while the content has been encoded in 22.2-channel format. Thus, an appropriate high-quality downmix has to be performed in order to enable the best possible listening experience, given the available speaker layout. In this way, the format converter allows universal output"*
>
> [Quackenbush, 2021, p1580]

As with other technologies such as Atmos, DTS-X and Auro 3D already discussed, the MPEG-H 3D audio standard provides users with the ability to interact with the audio content on a personal level [Herre et al, 2015, p770]. Historically the metadata has provided descriptive properties of the audio, such as title, composer, year etc. to help with production workflow [Herre et al, 2015, p772]. With MPEG-H technology, the metadata can be split into static and dynamic data points:

> *"Static metadata are considered to be constant for the duration of a program. Examples are a textual description of the audio element, e.g., its dialog language, and the default on/off state of an audio element. Dynamic metadata describe information that change over time, and control the rendering process, e.g., position, gain and spread of a virtual source used in the object renderer"*
> [Herre et al, 2015, p772]

Due to this feature, the audio related metadata provides various interaction possibilities, regardless of the playback scenario [ibid.]. The user therefore can control the audio mix, whilst selecting to adjust, add or remove a variety of audio content, providing customisable features for their personal preference [Meltzer et al, 2014, p6]. Such audio content may include different language tracks, which are useful to the visually impaired, whilst audio-scenes allow the user to control the mix between the dialogue and background tracks, or the commentary track [ibid.]. In addition, the metadata contains spatial information, providing the sound-objects location and possible movement within the 3D audio-scene, which can then be rendered for accurate location playback regardless of the user's playback system [Meltzer et al, 2014], [Simon et al, 2019] & [Herre et al, 2015, p772]. MPEG-H can also use HOA (i.e. soundfield technology) in combination with channel or object-based audio, as well as binaural rendering for customisable immersive audio on headphones [Meltzer et al, 2014, p4].

> *"this component is highly customizable and can be personalized by each individual user to adapt to particular listening preferences, for example with respect to the strength of the spatialization effect"* [ibid., p4]

The MPEG-H 3D audio standard demonstrates that it is a powerful and versatile platform for a variety of media functions, that may prove to be a leading format in the coming years.

With respect to virtual and augmented reality content, there is an extension of the 3D audio standard as a second layer currently in production called MPEG-I for immersive audio [Quackenbush, 2021, p1578]. The aim of MPEG-I immersive audio is to depart from a user static position, so that the user can move around in the virtual space, whilst using head and body tracking devices [ibid, p1584].

> *"For example, the user walks into a virtual restaurant, and there are many dinner guests talking. However, the dining area is small and loud, so the metadata must describe not only the other guests' positions and orientations but also the positions of the floor, walls, and ceiling of the room and the acoustic reflectivity of each. Furthermore, as the user walks from the restaurant door to their table, the audio must change since the user's position has"*
>
> [Quackenbush, 2021, p1584]

For the virtual world to be realistic to the user, the metadata must be significantly rich if the user is to feel immersed and fully present in that world [ibid.].

3.7 – Summary

Mono and stereo have established themselves as the champions of music recording and delivery for the best part of a century whilst continuing to lead the way, even in the application of more immersive audio environments. New technologies allowed for the development of surround sound, with the collective aim to create a bigger and better enveloping soundfield for the listener by simultaneously attempting to increase the size of the sweet-spot and the quality of the sound-image within a given space. From early 5.1 systems with surround sound on the horizontal plane to more enveloping 22.2 systems which also employ height (sound on the vertical plane), many of these systems still adhere to mono and stereophonic signals to produce greater localisation clarity and spatialisation. These surround-sound systems have played a significantly more important role in cinema than music performance, with limited use in music performance outside academic practice (see chapter 4). Similarly, Ambisonics has been employed in many research studies but remains on the periphery of the public sphere. However, object-based audio has already established itself as the new immersive sound technology due to its flexibility. It can be used for a variety

of surround-sound cinema systems, any large loudspeaker array, binaural audio, immersive audio for gaming, support for ambisonics, and many other broadcasting benefits.

Although binaural is a longstanding technology, it has become far more significant in recent years due to the increase in headphone use and products that support its application, particularly the use of AR and VR in gaming. This has been made possible due to the various computer-based technologies available, many of which are easily accessible and affordable.

Consumers are now able to listen to popular records on headphones, which have been mixed utilising immersive-audio techniques and rendered as binaural files, and can be consumed through streaming services. Some of these tools and processes have been discussed in this chapter (3.3), and will support the method in which this study collects evidence of its primary research (section C). Developers are utilising binaural technologies in conjunction with HRTFs to create immersive environments for the end-user. The notable progress of immersive-audio in gaming has been instrumental in the development of such technologies and the understanding of this field. Some consoles already support Dolby-Atmos and other immersive technologies such as Microsoft's own 3D Spatial Sound for Xbox and Windows devices. The gaming industry is now larger than the film and music industry combined, demonstrating a thirst by the consumer for multi-sensory experiences, which the industry is content to explore and deliver. The high budgets the game industry has at its disposal, along with the ubiquitous use of headphones by gamers for the purpose of audio isolation, provides the sector with significant opportunities for the further development of simulated immersive environments.

The primary research conducted in this study (section C) utilises mono and stereo signals during the development of the immersive projects, as this process is deeply embedded in music production. Certainly, the idea of mono signals suitably reflects the presence of a physical performer within a given performance space but in a virtual environment. Binaural recording, and in particular the accessibility of the Sennheiser soundfield microphone, will play a pivotal role in capturing the soundfield of each project as evidence.

As this study begins investigating immersive characteristics without loudspeakers, it is not until the final project in which mono and stereo signals are used to represent specific sound-

points within a surround-sound system. The application of loudspeakers already explored ranges from early to current spatial music practice. The 'main-8' octaphonic system presents many benefits, such as accessibility, ease of use, and robust sonic intelligibility (as discussed in chapter 3.4, and further explored in chapter 7.3). Its easy implementation as a surround-sound system on the horizontal plane which facilitates the minimum angle separation between speakers to produce solid localisation and spatialisation hearing, as well as plugins such as the Ableton surround-sound panner (limited to a maximum of 8 speakers), make this setup a very attractive prospect - hence its use in project 3 (chapter 11). Furthermore, this chapter has strengthened understanding of the manner in which humans process sound, such as sound-source localisation of both live performers and virtual-sounds in channel-based surround-sound systems. This information has therefore supported and influenced the arrangement formats employed in each original project (section C).

Very large speaker arrays, particularly with the use of height, which can exaggerate envelopment and increase the strength of the 3D spatial image are hugely appealing. However, such an opportunity remains outside the confines of this research at this stage due to the lack of such resource availability, but will undoubtedly be considered for future investigations where possible (chapter 12). Similarly, ambisonics and object-based audio will not play a key role within this particular study due to the technological demands. The recording, processing and reproduction of ambisonics is particularly laborious, without obvious benefits to this inquiry at this stage. However, where technology such as Dolby-Atmos and an enveloping loudspeaker array are facilitated within a performance space, object-based audio presents an attractive solution for the deployment of immersive sound. One of the many positives object-based audio offers is its ability to be effortlessly transferred from one surround-sound system to another. This is a useful tool that can support academic research, and therefore, it is more likely to appear in future investigations. It would be interesting to see how this usually mediated sound format for film and TV, can be successfully applied within a live performance context.

Finally, as the objective of this study is to examine the possibility of immersivity in music performance, it is characteristically tied to real-time presentation to an audience. Therefore,

techniques discussed for the production of immersive-audio in gaming such as HRTFs and simulated environments will not be considered for the duration of this study.

To summarise, mono and stereo, as well as binaural processing will be central to the primary research of this inquiry, whilst object-based audio exhibits many benefits that requires further consideration. Surround-sound systems, particularly the octaphonic-array will be a key delivery-format, whilst any potential to explore envelopment using sound on the vertical plane will undoubtably be considered in future investigations. The accessibility of object-based tools for the processing of 3D-audio presents a genuine opportunity for immersive music performance (similar to project 3, chapter 11) where loudspeaker arrays with elevation are available.

This chapter has sought to provide a clearer understanding of the technologies employed in previous spatial and immersive works. It has also better informed the theories argued in chapter 7 which deal with the taxonomy of immersivity (research question 1), in particular ideas surrounding sound processing, such as proximity, envelopment, localisation and spatialisation. Furthermore, it has provided some grounding on which technologies are useful to the primary research intentions of this research and how they can potentially be deployed (research question 2).

4. Music Practices

The field of music performance and in particular experimental music practices across research and academia have heralded various formats, methods and techniques, as well as the implementation of new technologies that need identifying and some clarification. This chapter critically explores the different practices with foundations in spatial and immersive music, with the purpose to consider established theories and techniques whilst identifying any potential gaps in practice which require further investigation.

4.1 - Electroacoustic Music

Electroacoustic music as Mooney [2005, p5] highlights can be “elusive” and “ill-defined”. The term electroacoustic music can encompass the two different compositional techniques formed by *Musique Concrète* and *Elektronische Musik*, whilst include performance paradigms such as the Acousmatic method, Sound Diffusion and systems that employ Ambisonics. Mooney [2005, p6] argues that the term can be problematic and confusing, due to the unclassified characteristics of *electroacoustic* parameters, whilst limitations if any, have not been clearly established [Caesar, 1992, p19] - the genre is therefore very difficult to define.

What is known is that the term *electroacoustic music* can be used quite generally for any music that is reproduced (partially, or in full) by loudspeakers [Mooney, 2005, p8]. Like the terms *Computer Music* and *Laptop Music*, it tells as very little about the constituent musical elements that define it, beyond the medium used to deliver it. It would not be useful to use the term ‘*piano music*’ for example [ibid, p7], or discussing genres such as *Folk* or *Reggae* without any indication of musical style. However, Mooney does try to establish some key characteristics for the electroacoustic genre. Beyond loudspeaker reproduction, *electroacoustic music* may include any fixed-medium playback device, such as tape, CDs, computers etc. [ibid, p9]. He goes a step further to establish the kinds of audio technologies electroacoustic music must employ in the following six categories [ibid, p22]:

1. Audio encoding technology,
2. Recording and playback technology,
3. Synthesis technology,
4. Audio processing technology,
5. Software (computer) technology,
6. Audio decoding technology

Menzies [1999, p3] asserts that the genre is associated with live performance, whilst there are experimental connotations attached to it and "conceived in the spirit of research" [Mooney, 2005, p40].

> *"electroacoustic' approach might negotiate the kinds of methodological choices … with a creative, experimental, artistic, or otherwise exploratory agenda"* [Mooney, 2005, p39]

Electroacoustic music is closely linked to the development of technology, where the manipulation of sounds through various different practices including effects, are incorporated in its compositional practice. It is therefore unsurprising that the term may have been intended to unify the early experimental methods employed by *Musique Concrète* and *Elektronische Musik* [ibid, p5].

Musique Concrète was pioneered by French electronic engineer Pierre Schaeffer, who in 1942 Paris begun research into the acoustics of sound, along with recording and playback technologies [ibid, p56]. Is it easy for us now with current technological advances to appreciate sounds as entirely malleable, where an original sound source can be manipulated into something completely new, and almost unrecognisable from its original state. This is what Nance [2007, p11] calls '*plastic*' sound, with Schaeffer innovating the idea of sound materials as '*plastic art'* through his experiments with musique concrète [ibid, p9].

The key concept behind musique concrète is to capture every day 'real' sound sources, such as household objects, voices, or those found in nature and industry onto analogue tape. Those sounds can then be cut, spliced, rearranged, stretched, played backwards and so on [Mooney, 2005, p57], to create new, sometimes unworldly and unidentifiable sounds, which can be used musically and intended for loudspeaker playback.

> *"'Real' sound occurs naturally, in the real world: it develops according to physical laws governing the interactions between the various sounding bodies that give rise to it."* [Mooney, 2005, p65]

Mooney [2005, p64] explains the musique concrète approach using Francis Dhomont description, where the compositional method begins with concrete sounds (pure sound material), which are then processed into abstract musical structures. This is the opposite to usual practice, in which the composer begins with an idea (the abstract) and ends with a completed and performable piece (a concrete outcome). Mooney expresses the musique concrète concept as a method in which composers can be 'architectonic' with sound materials [ibid, p68].

Schaeffer's compositional approach was to encourage audiences to listen to the intrinsic characteristics of sounds rather than interpreting what caused them [ibid, p58]; this is what Schaeffer called *reduced listening*. Although this idea is not new, audiences are still developing the skills needed to listen to music in such a manner because of how we are hardwired to associate sounds with actions. Due to technological developments, and the reduction of live performers at some concerts, it means that this listening paradigm is becoming more common ground, however, it could be argued whether this means that general listening habits have developed to Schaeffer's expectations.

Elektronische Musik was developed in Cologne, roughly at the same time as *Musique Concrète,* by a group of composers and academics, including Karlheinz Stockhausen [Ibid, p56]. Unlike Musique Concrète, Elektronische Musik was entirely electronic music made in studios using synthesisers [ibid]. A compositional approach that encompassed sonic materials entirely structured with no possible variations [ibid, p61], with every performance to be delivered as the composer intended [ibid, p58]. Just like Musique Concrète however, Elektronische Musik was derived in the spirit of experimentation due to new technologies available [ibid, p61].

> *"In the piece Solo (1966) the sound from a solo performer is passed through an arrangement of delays onto four speakers. Four assistants are required to manipulate the tapping points, switches and volume levels according to a*

precise sequence. The result is added sonic structure which correlates in a predetermined way with the scored solo performance." [Menzies, 199, p10]

Mooney [2005, p74] asserts that Musique Concrète and Elektronische Musik have therefore opposite compositional approaches:

- Musique Concrète is '*Top-Down'* – an organic perceptual approached intended to be interpreted
- Elektronische Musik is *'Bottom-Up'* – a structure conceptual approach intended to be realised. [ibid, p94]

Top-Down	Bottom-Up
Human	Super-human
Subjective	Objective
Composed to be interpreted/appropriated	Composed to be realised/disseminated
Realist (pragmatic)	Idealist
Plural	Absolute (monolithic)
Relativistic	Deterministic
Corporeal (physical)	Cerebral (intellectual)
Empirical/perceptual	Logical/conceptual
Qualitative	Quantitative
Phenomenological	Rational
Built/invented	Constructed/created
Organic	Architectonic
Abstracted forms	Abstract forms
Text submits to context	Context submits to text
Encoded audio streams are abstractions of the *subjective* (perceptual) qualities of real auditory events	Encoded audio streams are abstractions of the *objective* structures that define real auditory events

Figure 4.1 – Top-Down and Bottom-up Characteristics
[ibid, p84]

4.2 - Environmental/Soundscape Music

Described as a form of electroacoustic music by Parmar [2012, p1], *environmental music* is recorded sounds of acoustic environments. Truax argues that this is also known as *soundscape* composition - a musical form which must explicitly contain the sounds in their original form without manipulation [Truax, 2008, p105], and should not be treated as a

subgenre of electroacoustic music because of its unique approach [ibid, p108]. Truax may be asserting this view because this musical style has no clear connection (beyond loudspeaker reproduction) to the practices of Musique Concrète and Elektronische Musik, which are usually synonymous with electroacoustic music. It therefore cannot be related to acousmatic music either, but may attribute some similarities to Spatial Music practice. Truax [ibid, p106] sets out the following rules for soundscape composition:

a) *"listener recognisability of the source material is maintained, even if it subsequently undergoes transformation;*
b) *the listener's knowledge of the environmental and psychological context of the soundscape material is invoked and encouraged to complete the network of meanings ascribed to the music;*
c) *the composer's knowledge of the environmental and psychological context of the soundscape material is allowed to influence the shape of the composition at every level, and ultimately the composition is inseparable from some or all of those aspects of reality;*
d) *the work enhances our understanding of the world, and its influence carries over into everyday perceptual habits."*

4.3 - Acousmatic Music

In its simplest form, Andean [2014, p1] describes *Acousmatic* music as a form of *Electroacoustic* music that often uses tape recordings of sound material found in the world around us. Its origins lie in the *Musique Concréte* method established by Pierre Schaeffer in the 1940s and 50s, in which "sounds of the world become musical material" [Ibid.]. The term *Acousmatic* was first adopted in the 1970s by Francois Bayle [Ibid.], and is generally used to explain a compositional practice in which loudspeaker orchestras perform material that listeners can "no longer identify the source of a sound", whilst limited visual cues invoke auditory freedom and imagination [Caeser, 1992, p52]. As Stansbie [Ibid.] explains in a very pragmatic manner, Acousmatic Music is a "listening situation in which the source or cause of a sound is not presented visually to a listener". It is therefore appropriate for this musical practice to earn the name Acousmatic, as the word stems from the Greek word 'Akousmatikoi', which were a group of Pythagorean students. Roger Scruton explains the terms origins in his book *The Aesthetics of Music* and summarised by Stansbie [2013, p15] - "legend has it that Pythagoras conducted some of his teaching from behind a curtain in order

that the akousmatikoi could concentrate their attention upon the sound of his voice". Hence, the performance of composed material delivered solely through a 'Loudspeaker Reproduction System'. Jonty Harrison [1999, p2] goes a step further to provide us with some acousmatic music parameters:

- heard over loudspeakers;
- displays an acousmatic intent (not merely a substitute for another listening mode)
- composed on and exists on a fixed medium;
- the physical source (if any) of the sounds is not actually present at the time of listening;
- the source, nature or cause of the sound may be unknown or unknowable;
- the compositional criteria extend beyond what is normally considered 'musical'

Andean [2014, p1] adds that sound sources are full of 'hidden musical potential' where the artist/composer is free to "edit, treat, manipulate" material to create unique compositions, in which the original identity of the sound is removed from its identifiable qualities and redefined [Ibid.]. Acousmatic music is not devoid of all visual content however, as our experiences of music in which we instinctively imagine visual cues to the auditory content and the sounding space, cannot be easily disconnected from the overall performance experience [Smalley, 2012, p40].

> *"The unique beauty of the genre lies precisely in this duality: the purely musical world on the one hand, where the sounds are composed and appreciated for their musical or sonic properties, and on the other hand, the stream of sources and imagined gestures that these sounds evoke. Any and all sound material used will tend to contribute to both of these two streams: a sound will always have musical properties, and will also always have the capacity to evoke some kind of real-world imagery".* [Andean, 2014, p2]

The term *reduced listening* coined by Pierre Schaeffer as a "listening paradigm, in which the source of a sound is deliberately ignored in order to focus on its sonic qualities", can form rhythm, timbres, textures and melodies [ibid, p1]. However, Andean explains that this listening paradigm does not come naturally and therefore listeners will need to actively ignore (if possible) the real-world sound sources to fully appreciate the compositional qualities of the music [Ibid.]. Schafer devised the term '*schizophonics'*, in which the altered sound has

been divorced from its original source "torn from their sockets and given an amplified and independent existence." [Barnard, 2010, p32]

> *"If we subscribe to the assumption that all sound is potentially musical and that music itself is simply a method of listening, we can turn our attention to the potential musicality of the sonic environments we are continually experiencing. The world is performing a constantly unfolding, naturally occurring composition, of which we are all part: we just have to listen."*
>
> [Barnard, 2010, p6]

As explained above, Mooney [2005, p84] argues that Acousmatic music invokes the 'top-down' compositional approach, in which pure concrete sounds are developed into abstract musical structures [Hewitt, 2006, p5]. Caesar [1992, p22] explains that the liberty given to audiences to interpret the music as they wish, and invent their own 'mental image', is fundamental to the acousmatic method. Listeners can create their own "explanations of the sounds they hear", an element that is lost in instrumental music due to the gestures and actions that produce those sounds [Ibid, p22]. We can therefore envisage the direct link between musique concrete and acousmatic music through Nance's explanation of '*plastic art'*. This is another key element of the acousmatic method, in which the performer can manipulate sound sources in real-time to deliver their own interpretation [Nance, 2007, 61]. As with all electroacoustic genres, technology is key to the production and performance of acousmatic music.

> *"Recording and amplification technology allow the composer to remove sounds from their causal context and in re-contextualising sound, the composer can manipulate important semiotic indicators"* [Hewitt, 2006, p9]

The Acousmatic music method is therefore tightly linked to 'Sound Diffusion', which is "the projection and the spreading of sound in an acoustic space for a group of listeners—as opposed to listening in a personal space - living room, office, or studio" [Austin, 2000, p10], with the aim of the sound to be moved around the space to envelop the listener [Dow, 2004, p2]. To achieve envelopment, sound diffusion requires a loudspeaker 'orchestra' (a large number of speakers), at minimum a 5.1 surround or eight-channel system [Otondo, 2008, p80], but larger loudspeaker orchestras are more effective for this delivery method.

4.4 - Sound Diffusion

Sound diffusion is a type of public performance of electroacoustic music to an audience [Mooney, 2005, p99], in which *sound* is *diffused* within a performance space using spatialisation techniques [Menzies, 1999, p65] - it is therefore by design, a *Spatial Music* performance medium. The music and sound is diffused (spatially distributed) using multichannel speaker systems, in which a central performer (a diffuser) responds in real-time to the aesthetics of the space and the music and sound being performed within it [Perepelycia, 2006, p77].

> *"diffusion takes a stereo image and projects it during the performance into the performance space via multiple loudspeakers, guided by a performer at a mixing console, usually centrally placed."* [Truax, 2008, p105]

In sound diffusion, the diffuser can illuminate the perceived location of various sound sources using phantom imaging techniques (not emanating from a specific speaker or set of speakers), by placing and moving the sound source anywhere within the soundfield (fairly freely depending on the speaker system and setup) [Mooney, 2005, p32]. The displacement of sound between loudspeakers using panning and amplitude methods can help to create an "illusory space" [Lotis, n.d., p66], and an "emancipation of spatiality" [Mooney, 2005, p32]. Unlike fixed sound projection in which sound images are projected to specific speakers within a loudspeaker array, live diffusion moves sound objects around the array.

> *"most listeners will realise that in reality the loudspeakers are the source of what they are hearing, but perceptually the sound sources will be invisible, because there is no visible entity fixed at the location from which sound seems to be emanating"* [Mooney, 2005, p32]

Speaker systems and the performance space (room acoustics) will greatly influence the diffusion process and the perception of the music. This is why an electroacoustic composition can never be accurately reproduced in different spaces, in which the original ideas (almost always composed in a studio rather than using a sound diffusion system) will be compromised by the speaker system and room [ibid, p105]. This is where the role of the diffuser is central to the process, by interpreting the piece for the space it is performed in [Menzies, 1999, p65].

As Ambrose Field explains, that although some considerations on the diffusion process can be made during the production process in the studio, ultimately, it is up to the diffuser to move, place and localize sound in real-time during the presentation of the work (Austin, 2001]. Mooney [2005, p104] explains the issues a diffuser will experience as follows:

- *"The distances between audience members and loudspeakers is problematic*
- *This compounded when the space is increased and the reverberant space is larger*
- *Which decreases the integrity of the phantom image and timbral qualities*
- *Which is compounded by varying levels of speaker power and sound intensity at different distances"*

The HDLA systems (high density loudspeaker arrays) including octaphonic and upwards applied in sound diffusion such as the BEAST system at Birmingham University, provides imaging over the entire 3D soundfield, enlarging the 'sweet-spot' and reducing the 'spatial holes' [Dow, 2004, p2]. The traditional models of most musical performances that most consumers are often exposed to, such as the stereo image used in concerts and theatres, is unable to create a 3D audio experience, therefore sound diffusion is "inherently more immersive" [Truax, 2008, p105].

In HDLA systems where identical speakers have been distributed equidistantly from each other to minimise error [Wozlniewski et all, 2006, p145], sound diffusion composers are able to control the image. Larry Austin [2000, p17] wants his audience to be entirely unaware of the speakers, because as he explains, through diffusion methods "the speakers actually have absolutely nothing to do with where the sound is coming from" [Austin, 2001, p28]. The control of the image and 3D soundfield is an integral element in the diffusion method.

> *"one should be able to expand these dimensions: … exaggerate closeness, exaggerate distance, play with the height of the image, thereby adapting the space composed into the music to the dimensions of the listening space."* [Austin, 2000, p12]

Electroacoustic music is rarely composed with large loudspeaker arrays in mind, nor the listening space. Sound diffusion however, allows the performer to adapt the work for that particular performance space [Austin, 2000, p11] due to the various sound diffusion possibilities available. Maybe the limited ability for a composer to write a work with an HDLA

or within the listening space is why Ottondo [2008, p80] believes that although the technology is available, rarely are artists pushing the boundaries. Harrison [1998, p126] may disagree, sound diffusion methods are able to vanish the localisation of sounds within the loudspeaker boxes, "to keep the sound in a constant state of spatial evolution". This an element that is unheard of in commercial settings, where localisation and gesture are interlinked in most live performances. Larry Austin explains that the experience of the diffuser is essential in creating this effect, but over-diffused performances can create an "undesirable separation between the instrument and the electroacoustic environment" [2000, p14]. Natasha Barrett believes that for spatial listening to be fully explored, any visual content should be removed entirely [Barrett et all, 2018, p400].

4.5 - Spatial Music

The term *Spatial Music* encompasses music forms in which the technique of *spatialisation* is central to the performance, where sound localisation cues are key to producing sound movement within a space. This can be achieved in two ways: 1) the movement of a sound image within a loudspeaker array, varying from a quadrophonic system to a very large loudspeaker array (HDLA) or 2) the movement of a performer within the space. The term *spatial music* can therefore be used fairly broadly for any music that exhibits these characteristics. Spatial music has its roots in spatial hearing, which is our natural ability to distinguish sound sources, their location and movement. Composers over time have implemented this enate ability within music practice, whilst technology has provided even further scope for creators to explore spatial characteristics. As Kendal explains, for us to better understand spatiality and its use in electroacoustic music, we must better understand how the human experience assigns meaning to sound [2010, p228].

> *"The feelings and thoughts that the listener associates with the experience of sound in space appear to arise from a deeply embodied knowledge of space and spatial movement."* [Kendal, 2010, p228]

Localisation is a key aspect in Electroacoustic Music in methods such as Ambisonics and Sound Diffusion, in which the aim is to recreate and manipulate a 3D audio environment. Harley

[1998, p148] explains that “spatial projection, sound location and direction” can become important structural elements in the music known as ‘spatialisation’. The listeners ability to localise sounds in a 3D audio environment is known as ‘audio spatialization’, ‘audio rendering’, or ‘sound imaging’ [Wozlniewski et all, 2006, p144].

Localisation is easier for a listener when the sound is moving than when stationary [Malham, 1995, p66], such as moving signals front to back to give them more spatial qualities [Austin, 2000, p13]. This is also the case with sounds that have sharp attack characteristics and those with wide band signals [Malham et al, 1995, p66]. As Harley [1998, p150] explains, spatial separation is therefore important for the following reasons:

1. “Spatial separation clarifies the texture; this is particularly important if the music consists of several different layers located in the same pitch register.
2. Spatial separation is equivalent to the separation of textures in pitch space; one can hear separately layers of music that are located in different registers, and layers that originate from distant points in performance space.
3. Spatial separation permits a greater complexity in the music; which may, therefore, include more unrelated elements perceived simultaneously.
4. Spatial separation makes exact rhythmic coordination impossible; distant groups should avoid simultaneous, identical rhythmic patterns.
5. There are no optimum positions of the listeners or the performers in the hall; each situation is different.”

Barnard [2010, p35] coins two relevant terms; *object motion* which relates to the autonomous movements of sound within a space, and *frame motion*, which relates to the enveloping movement of a virtual environment. Barreiro [2010, p291] defines the *composed space* as the pre-determined musical work that contains spatial characteristics, and the *listening space* as the acoustic characteristics of the performance space.

Electroacoustic music developments have been key in the exploration of space as a primary parameter within music performance [James et al, 2013, p1]. Acousmatic music is a concrete example of this approach, in which “space and spatial experience are aesthetically central” to

the compositional process [Smalley, 2007, p35]. With advancements in multichannel systems, the spatial approach can produce experiences that envelop the whole audience, creating an immersive sensation [Barreiro, 201, p292]. Composers of spatial works must be able to control various parameters to achieve this such as "volume, spatial dimension, spatial location, depth, height, motion and spatial behaviour, distance and presence, and reverberation" [Macdonald, 1995, p81].

Spatial music however is not new, as we have highlighted in chapter two, it has been explored by composers for centuries within different scenarios, where creators have had to produce and/or adapt their music to suit that particular space. New technologies have given spatial music new opportunities, with multiple options available to composers who need to catch up and take full advantage of these possibilities [Ottondo, 2007, p17]. It is also up to venues and concert halls to install systems that allow musicians to explore the space in a commercial sense, so that this approach is not limited to experimental practice.

Boren at al [2018, p1] argue that spatialisation in music could be considered the third compositional paradigm to be added to western music practice, with tonality (pitch) being the primary function and time/rhythm secondary. Both Ives and Brand utilised space to expand the scope of music beyond the tonality paradigm [ibid. p2]. Technology, especially binaural and ambisonics technology, coupled with loudspeaker arrays, fitted with hardware and software applications that makes spatialisation more common practice, have all elevated the idea of space as a musical concept. Boren et al set out three practical theories within the spatialisation paradigm. 1) *Spatial Dissonance & Consonance* - rooted in the application of tonality to create dissonance and consonance, spatialisation can create the same emotional effect, in particular the realism and clarity of sound sources [ibid, p3]. 2) *Spatial Position* - as with popular music which centres important elements with a higher amplitude, the status of sound sources within spatialisation can depend on their application, position and movement relative to the listener [ibid].

> *"Events that are placed as point sources, front and center in relation to a listener are more likely to be perceived as 'important' material. Likewise, sound events that are diffuse and seem to inhabit a large portion of the ambient lateral plane are likely to be perceived as supporting, background, or secondary".* [ibid]

3) *Inertia & Gravitation* – considers the spatial trajectories and elevation of the sound. In the first instance sound source trajectories should remain consistent. Secondly, elevation is dependent on frequency, in which higher pitches are processed as being physically higher, and vice-versa for lower pitches [ibid].

The research conducted by Peters, Marentakis, and McAdams [2011, p12], in which they surveyed composers from across the globe on the technological and compositional practices they used for Spatial Music was illuminating. Results revealed that live and prepared electronics are the most popular in installation and concert work, with most composers stating their primary artistic spatial goals were to 1) "enhance the listening experience, 2) artistic expression and 3) organise and structure sounds", articulated in that order of popularity [Peters at all, 2011, p12]. The artists conveyed their belief that listeners found the immersive paradigm such as enveloping sound, more interesting than the "traditional frontal stage" method [Ibid.]. Artists were also quoted in their assertion that spatial music allowed for more "complex music to become more comprehensible" and provided space for innovation [ibid, p13].

Many composers agreed that the distribution, position, depth, distance, the size of spatial image, as well as movements of sound (whether from the phantom images from loudspeaker or the movement of performers in the room), were core attributes in achieving a spatialised sound experience [ibid, p14]. A commonality expressed by many composers in the survey (also experienced by the author), is the difficulty of finding appropriately resourced acoustic spaces. Therefore, the majority of composers continue to use traditional concert halls, whilst some have access to specialised venues with the minimal expectation of the most popular spatial setup – the octaphonic array [ibid, p16].

On the matter of compositional practices, the three most important popular spatial features were 1) immersiveness, 2) localisation accuracy of sound sources, and 3) creating a slow subtle movement of sound sources [ibid, p28], with panning within the audio sequencer as the most popular technique used [ibid, p25]. All three methods have been at the core of this study, and will be employed in the original works reviewed in section C.

4.6 - Summary

Although electroacoustic music is difficult to define, it certainly contains some conclusive conditions such as the use of loudspeakers for performance to a live audience, and its connection to experimental methods. This study therefore will deliver projects that loosely relate to electroacoustic practice, as all the projects discussed in section C are live performances to an audience, whilst project 3 includes a loudspeaker array. However, the music itself will not be experimental in nature, comprising compositional techniques more common to contemporary popular music. This is to ensure that the music remains broadly accessible to a wide audience demographic, whilst ensuring the primary research is focused on investigating the immersive parameters employed. The soundscape method will not play a role in this study at this stage due to the author's limited experience in the field, and for the purpose of intentionally developing a palatable music project.

The original works presented in section C consist of a 'bottom-up' approach, in which the works are entirely conceptual, and constructed to be played back nearly identically, therefore taking much of their influence from Elektronische Musik. Again, this is to ensure the music is consistent, especially when conducting research that may use varied delivery formats (as in Project 1 – chapter 9). However, there are some influential elements taken from Musique Concrète and the acousmatic method with regard to real-time sound manipulation (employed in Project 3). There will be some intrinsic application in the processing of sound materials during the production process and in real-time performance, but it could be argued that this is a natural manifestation of contemporary production techniques and computer-based performance methods. Musique Concrète and the acousmatic method have clearly had a lasting influence on music production and the way in which real-world materials or instruments are processed in contemporary music to create unique and innovative sounds. However, for the duration of this paper, the acousmatic method will not play a significant role in the investigative methodology. The intentions of the three original projects, will actively explore the audience's perception of physical actions (rather than reduce them), by employing visual and sound processing methods to increase gesture, utterance and agency (explored further in chapter 7).

Sound diffusion is a performance medium that has been well-established by prominent academics and composers such as Larry Austin, Jonty Harrison and Dennis Smalley. These individuals have had a significant impact on the field of spatial music as well the general understanding of electroacoustic music post-Musique Concrète and the Elektronische Musik era. Although the methods employed in sound diffusion, especially the HDLA systems are outside the scope of this inquiry, much of the academic research in spatial music has stemmed from the experimentation undertaken within the sound diffusion method. Therefore, it has directly and indirectly influenced the works of this study, such as the use of loudspeaker arrays, space and sonic image, as well as gesture and agency.

Sound diffusion is unquestionably a type of electroacoustic music, with much of its practice influenced by the acousmatic method. However, as critically explored in chapter 7, immersivity in music performance relies on clear visual cues, physical actions, proximity and audience engagement. It can be surmised that sound diffusion and immersive music performance in the scope of this research do share some similarities, but there are also inherent differences. There are elements discussed thus far in sound diffusion that influence the immersive aspects of this study, such as the control of a sounding space through the use of loudspeaker arrays to best envelop the listener. Although there is a visual presence of the diffuser in some circumstances, it is not a condition of the method. Whereas this study seeks to enhance the visual presence of musicians to investigate the importance of physical action in immersive music performance.

As we have previously explored, spatial music relates closely to immersive music practice. However, a live music project does not require spatialisation techniques to be considered immersive, but it is clear it does enhance listener perception (further explored in chapter 7). The physical and virtual movements of sound (live performer and phantom images respectively) will play an important role in the primary research of this study, particularly in regard to how this can be positively accomplished without negatively effecting the compositional integrity of the music. This chapter also emphasises how surround-sound speaker systems can benefit music which contains complex compositional structures by providing better sonic intelligibility due to enhance point-source separation.

This chapter has provided clarity on the music practices examined and previous approaches, whilst contextualising these against the investigative aims of this inquiry. Many of these practices and their outcomes have informed the investigative intentions of research question 1, in particular the importance of envelopment, as well as concerns surrounding sound and visual processing. As these practices have already laid the foundations for immersive music practice, they have directly informed methodologies highlighted by research question 2, which seeks to further the understanding of this field through the primary research. However, the gap in research practice this paper has outlined, corroborates the conclusions discussed in chapter 2.2 regarding previous notable works. This gap is the lack of an audience-centred compositional approach present in immersive music academic practice. The importance of this methodological approach, coupled with the need to investigate audience perception, especially when trying to define a new paradigm within music performance is further articulated in chapter 7.5.

5. Methodologies

This chapter introduces academic methodologies common in creative-arts research, which including practice-based and practice-led approaches. As discussed in the research aims (chapter 1), due to the significance of participants in this study, methods to record data through questionnaires are implemented. The purpose is to utilise good practice to ensure meaningful data collection against the research aims.

5.1 - Practice-Based and Practice-Led Research

> *"Research that takes the nature of practice as its central focus is called 'practice-based' or 'practice-led' research."* [Candy, 2006, p2]

This type of research is usually undertaken by creative practitioners, particularly those in the arts and education, allowing for the development and contribution to new knowledge through alternative methods [ibid.]. Such research may focus on an individual's personal and professional development with the aim to realise an objective or vision, rather than a shared purpose [ibid.]. Instead of an outcome that is solely presented in the written form, it may also include physical, artistic, or symbolic forms, that are supported by a thesis. As Haseman explains, words alone do not "capture the nuances and subtleties of human behaviours" [2006, p101]. This type of research practice is important because practice should be informed by research, and research should be informed by practice; the two worlds should be intertwined whilst approaches should be holistic [Fox, 2003, p81]. Haseman explains that the 'practice' segment of practice-led research is primary, not an optional extra [2006, p103]. Fox [2003, p83] uses the description by Haines and Jones that "researchers see data, while practitioners see people", and therefore for data to be relevant it must consider practice-based approaches, before the data is contextualised into real world practice.

Candy [2006, p1] defines practice 'based' and 'led' research as follows:

Practice-Based: *"If a creative artefact is the basis of the contribution to knowledge, the research is practice-based."*

Practice-Led: *"If the research leads primarily to new understandings about practice, it is practice-led."*

In practice-based research the contribution to knowledge, outcomes and assessment, can take the form of *original* creative practice as an *"artefact",* such as an exhibition of artistic material, a portfolio of musical compositions and/or performances, digital images, designs, videos etc. [ibid, p1]. Haseman calls these "the symbolic language and forms of their practice" [2006, p100].

In research that is practice-led, the aim is to advance our knowledge about the practice itself through practice [ibid.]. In this case, the investigative aims are focused on the processes that lead to particular outcomes, which Haseman calls "intrinsically experiential" [2006, p100]. Draper and Harrison [2011, p90] use Gray's definition for practice-led research as:

> *"research which is initiated in practice, where questions, problems, challenges are identified and formed by the needs of practice and practitioners; and secondly, that the research strategy is carried out through practice, using predominantly methodologies and specific methods familiar to us as practitioners in the visual arts"*

The Arts and Humanities Research Council [AHRC, 2021] has defined research as follows:

1. "It must define a series of research questions, issues or problems that will be addressed in the course of the research. It must also define its aims and objectives in terms of seeking to enhance knowledge and understanding relating to the questions, issues or problems to be addressed
2. It must specify a research context for the questions, issues or problems to be addressed. You must specify why it is important that these particular questions, issues or problems should be addressed; what other research is being or has been conducted in this area; and what particular contribution this project will make to the advancement of creativity, insights, knowledge and understanding in this area
3. It must specify the research methods for addressing and answering the research questions, issues or problems. You must state how, in the course of the research

project, you will seek to answer the questions, address the issues or solve the problems. You should also explain the rationale for your chosen research methods and why you think they provide the most appropriate means by which to address the research questions, issues or problems."

The actual structure, process, outcomes and assessment of a practice-based or -led doctoral research, is likely to be further defined by the University and their doctoral college regulations [Candy, 2006, p2]. Draper and Harrison [2011, p86] highlight Hannan's point that because university guidance and expectations are likely to vary, so will academic and artistic standards. Candy [2006, p2] explains that a thesis is "expected to both show evidence of original scholarship and to contain material that can be published or exhibited". What is different between practice-based and conventional research, is that original processes and outcomes themselves are accepted as a demonstration of contribution to knowledge [ibid.]. However, similarities exist in which researchers must still exhibit critical analysis, mastery and contextualisation of their work within their field of practice, in a manner that is "accessible" and "auditable" by their peers [ibid, p3], so that outcomes can be "verified" or "challenged" [ibid, p5]. This is why a literature review is a vital segment of the research, as it provides context and supports one's arguments, in some cases highlighting a gap in knowledge or practice [ibid, p8].

Fox [2003, p84] provides three arguments for the purpose of Practice Based Research (PBR) as an alternative model to conventional research methods

1. "Practitioners know best and should be left to get on with it, free of interference from the professional researcher (the conservative view).
2. Practitioners are lacking in key knowledge and ways must be found to re-educate them into effective service delivery (the evidence-based practice approach).
3. Rather than blaming practitioners for disregarding research evidence, the fault lies with the model of research which has been developed in academia. This research model does not readily articulate with the practical imperatives of service professionals. Research does contribute knowledge, but it is up to the researcher to change her mode of working so it contributes to practice."

Practice-based research is relatively new in academia, having begun in 1984 in Australia, where two universities established new doctorates in Creative Writing [Candy, 2006, p4]. The idea that one's own practice, could itself be deemed as research was completely new [Draper et al, 2011, p91]. However, we should establish that simply doing research as part of one's practice is not accepted as doctoral research, because it must meet fundamental PhD practices in which researchers attempt to answer key questions within the practice itself.

This approach stems from a history in research, and the search for knowledge or 'truth' – what, why, how? Practice-based and led research provides us with new approaches to solve new questions in our never-ending search for understanding. The famous Socratic quote – 'all I know, is that I know nothing' – still stands true, in the sense that knowledge is always in flux, and therefore never constant. Candy [2006, p5] supports this statement, that "we cannot know any general truth about the world for sure", whilst Fox [2003, p86] re-affirms this notion that "neither research nor practical experience can ever provide a single or universal 'truth' about the world". This concept may be even more pertinent in some practice-based research, in which audience expectations and perceptions are central to the study. Human subjective responses themselves are in constant flux and prone to influence, therefore the idea that we may find a constant, is likely to be a general and momentary assertion. However, as we have explored thus far, practice based and led research are new but pivotal approaches in advancing our understanding of a field, in particular where creative practice is the mode of work.

Difference in practice-based and led research from conventional research, means that in some cases, researchers using these approaches may struggle to find suitable methodologies within the established qualitative and quantitative modes [Haseman, 2006, p98]. Haseman continues to explain that researchers find that these orthodox approaches are not "sympathetic to their fundamental beliefs about the nature and value of research" [ibid.]. Candy [2006, p7] provides some guidance on methodology - a potential structure and approach for practice-based research:

1. *The Problem* - A concise statement of the research question or issue that the thesis addresses.
2. *The Context* – What is the purpose of this research and what knowledge does it hope to contribution?
3. *The Method* – What approaches will be used to attempt solving the problem or answering the issue (experimental, practice based, analytical etc).
4. The Outcomes – Summarise point that are key contributors to knowledge.

Fox [2003], provides the following methodology

1. Setting a Research Question
2. Research Design, Study and Instrument Validity
3. Data Collection and Reliability
4. Data Analysis and Hypothesis Testing

There are similarities between the two methods, as well as the methodology used in this study outlined in section C.

Fox [2003, p90] supports the assessment that doctoral research must contain a clear question, where the quality of the research will be judged against the extent to which the question has been answered. However, he explains that this approach assumes that research is linear, a methodology that is not particularly suitable for practice-based research, which is more open-ended [ibid, p94]. In these two research approaches, it would be deemed reasonable for the correct question to be established when the researcher has a better understanding of the setting in which the research will take place, so that research questions are directly linked "to the specificities of the setting" [ibid.]. The research questions should also consider the length of the study rather than single investigations, where theoretical considerations are directly linked to relevant practice, and the concerns of professionals in that field [ibid., p91].

When such considerations are made, it is probable that research designs need to vary to fully answer the research aim and its various potential settings [Fox, 2003, p92]. This is what Fox calls [ibid.] a "period of exploration", a time in which the research questions and methodologies are developed based on the research settings, and its potential participants. Fox uses various educational, classroom-based examples to clarify his methodology for

practice based and led research, which must consider the setting, its students, as well as their individual socio-economic backgrounds [2003].

Some issues from PBR processes may arise with respect to the validity and reliability of the data collected, especially if the study varies the questions being asked [ibid., p93]. To clarify, issues with validity is what Fox calls "systematic error", whilst reliability is an issue with "random errors" [ibid.]. As in this particular study, it is therefore important to establish clear parameters to test against (immersivity), so that data can be collected, assessed and synthesised against those established parameters [ibid.].

As we have recognised already, the PBR approach to research is likely to be more open-ended, therefore less concerned with conclusive outcomes, and more interested in the "ongoing process of evaluation and reflection", that will likely lead to further investigations [ibid, p94]. However, established theories through research, should make recommendations to practitioners in that field, such as changes in practice [ibid.].

Haseman provides an argument on the merits of quantitative and qualitative research in reference to practice-based research. In the case of quantitative research, which relies on qualifying results through statistics, he asserts that this approach undermines the individual perspective of the researcher [2006, p99]. Qualitative research on the other hand, which observes and interprets behaviours, can contain fairly broad strategic methods that embrace individual perspectives, from both the researchers and participants [ibid.]. In some studies, which rely on investigating human perception, "subjectivity and bias would be seen as advantages" [Fox, 2003, p93]. Both approaches however, must be designed to answer the key question being asked or problem being solved, whilst being grounded in theory, and demonstrate a clear understanding of the field being researched [ibid, p100].

We have established the principles of practice-based and led research, structure and methodologies whilst considering the traditional practices embedded in quantitative and qualitative research. Haseman [2006, p103] argues that Practice-Based and Practice-Led research, should be considered as a singular third paradigm called 'Performative Practice', in addition to quantitative and qualitative research approaches.

> *"performative researchers progress their studies by employing variations of: reflective practice, participant observation, performance ethnography, ethnodrama, biographical/autobiographical/narrative inquiry, and the inquiry cycle from action research"* [ibid.]

Haseman believes that the methods developed by performative practice will eventually influence the traditional quantitative and qualitative methods, with more defined and rigorous research strategies [ibid, p105].

5.2 - Participant Questionnaires

Research has shown that various elements should be considered when formulating a questionnaire, indicating that there is no universal method for best practice. The objective is that each questionnaire is designed to be project specific, with the intention to best capture "reliable, valid and unbiased data…, in a timely manner" [McColl et al, 2001, p3]. Arsham [2005, p2] suggests, that when planning a questionnaire, the advantages and disadvantages along with the objectives, should be initially considered. He adds, that once clear objectives are outlined and the questionnaire is feasible, the author must ensure to have it checked by others before proceeding [ibid.].

The questionnaire should be clearly presented and in an order that reflects the project's investigative intentions [McColl et all, 2001, p3]. The structure and relevance of the questions can help participants process the enquiries in a logical manner that makes sense against the study, which in turn, allows the author to decode the responses effectively [ibid.]. McColl and team further suggest that priming participants in advance along with friendly reminders, can yield a higher response rate - interestingly, anonymity has not proven to affect the quality of responses [ibid.]. It is recommended that qualitative and quantitative data is collected for greater scope, whilst analysis of the quantity and quality of responses should be examined to determine trends in responses, that may have been affected by the question format [Ibid, p4].

A *self-administered questionnaire* is one which participants complete independently, and as there is no interviewee, questions must be clear and well-defined for greater quality in participant responses [Jenkins et al, 1995]. The work of Petra Lietz [2010, p.265], which includes a thorough review of various studies, provides a clear and robust model:

- Questions should be constructed to be as clear, simple, specific and relevant for the study's research aims as possible.
- Effectively communicate the language used, and reduce complex terminology, to avoid socially desirable responses (a response which may be deemed as favourable by society).
- Reduce any cognitive load to free mental capacity for responding.
- Complex questions should be separated into smaller ones that are easier to comprehend, avoiding 'double-barrel' questions.
- Avoid vagueness - words such as 'possibly', 'usually', 'frequently' etc.
- General questions should precede specific questions.
- A desirable scale length ranges from 5 to 7 response options, where the inclusion of a middle option increases the validity and reliability of a response scale slightly.
- 'Extremely' and 'not at all' can serve as most effective verbal intensifiers.
- A 'don't know' option can be considered, where appropriate.

The scales which range from 5 to 7 responses (or more if desired) refer to the 'Likert' scale, a psychometric tool used in social sciences to determine the level of agreement a participant has, to a given statement on a defined metric scale [Joshi et al, 2015, p1 & 2]. It is challenging for researchers to quantify the subjective perception of a participant objectively, as there is no conventional measurement that can achieve that [ibid, p2.]. A Likert scale enables researchers to quantify the 'unquantifiable', with qualitative research attempting to compensate for what scales and numbers cannot achieve, which is gather data on "attitudes, perceptions and opinions" [ibid.]. Another example of a quantitative psychometric scale is the PANAS test (Positive and Negative Affect Schedule) [Watson et al, 1988]. In this assessment a list of 20 emotions are placed against a Likert scale ranging from 'not at all' to 'extremely', or 1 to 5. However, this method of participant emotions may be too broad or not

applicable to a particular study, and therefore researchers may wish to make amendments and variations suitable for their investigative needs, by using relevant types of emotions.

5.3 - Summary

This study has taken influence from both practice-based and -led approaches, or using Haseman's description of 'Performative Research'. The practice-based method is supported by a series of artefacts (original projects), consisting of live performances to an audience and supported by audio-visual evidence. The practice-led method will be evidenced through an on-going research methodology where practice in the form of investigative projects accompanied by participant questionnaires, are assessed to inform further practice. This is particularly important in relation to the key research questions, with the aim to better understand what constitutes immersivity in music performance. Additionally, the use of traditional research methods, such as the collection of qualitative and quantitative data will help to inform all of the indicative research questions by strengthening understanding of audience perception against the immersive parameters employed. This supports the original assertions that audience perception is not only integral to the investigative aims, but indeed advantageous within the scope of this study. In all, this paper demonstrates an innovative approach to academic inquiry by incorporating a blended research methodology.

Beyond the discussed methodology, this chapter emphasises other important research components that must be considered. This includes the significance of a literature review to contextualise the subject and to outline gaps in knowledge and practice requiring further examination. Additionally, the investigative inquiry has been supported by clearly defined research questions from the outset. Guidance provided by this chapter on the purposes and outcomes of academic research in general have been considered, and thus, have influenced the structure of this thesis. Finally, it is worth noting that performative research practice, as clarified by Fox, will likely lead to or require further investigations beyond this present research – as outlined in chapter 12.

The project methodology presented in chapter 8 echoes the methodologies suggested by Fox and Candy. Their outlined methodologies use different language, but consist of four similar phases of inquiry. These are justifiable approaches for the primary research scope in this study. The first phase poses a question that needs answering, in this particular case, it is the research questions outlined in chapter 1 with respect to composing music for an immersive project. The second phase requires the researcher to design a project to answer, or at least attempt to answer, the key research questions being asked. The third phase is the collection of data, before using the data to infer outcomes. The outcomes provide useable information to support the scope of this study, whilst presenting opportunities for further investigations to take place. This cyclical process realises the practice-based and led approaches this study requires to effectively investigate immersivity in music and to attempt to define it as a performance paradigm.

For the purpose of this research, many of the points listed by Lietz [2010] were considered for each project questionnaire with the aim of effectively capturing valid and reliable responses against the application of immersive characteristics. Each questionnaire therefore considered the investigative aims of each project, with particular importance given to the employed immersive characteristics. If specific immersive elements were being tested such as proximity for example, then the questions needed to be formulated with this in mind. Likert scales were used to quantify participant responses against specific statements surrounding the application of immersivity. A combination of qualitative and quantitative data was collected to broaden the understanding of audience expectations and perception.

Finally, the format, structure and language used were designed to ensure effective audience participation, captured in a timely manner. For this reason, each project employed an objectively standardised process for consistency and parity. Each questionnaire of approximately 10 questions was generated in the form of an online survey using Google Docs, was sent via email to each audience member prior to the delivery of the performance. The self-administered questionnaire contained an opening statement to provide context to participants. Participants were reminded at the end of the performance and shortly afterwards via email, to complete the questionnaire at their earliest possible convenience to reduce any lapses in memory. This method was preferred, as it allowed each individual to

complete the questionnaire in their own time, without time restrictions or pressure that could arise from written or digital surveys post-performance.

The blended performative research method discussed, along with the consistent project methodology and a robust participant inquiry outlined, were all carefully selected and designed to appropriately respond to the research questions. The primary research outcomes of chapters 7 to 11, demonstrate the effectiveness of the methodologies applied in fulfilling the research aim.

6. Gaps in Knowledge & Practice

This chapter responds to the gaps in knowledge and practice recognised in the literature review thus far, expanding further on arguments already made. The gaps discussed here directly influenced the research questions. The nature of this research along with its key aim was to critically investigate the practice of immersivity in music performance through a literature review supported by original compositions. It was always the intention of the primary research process to experiment with 1) composition and 2) performance material, through 3) unique delivery methods; with all three elements directly intertwined to produce a cohesive and unique listening experience. From very early on in this study it was clear that those three components would need to be considered holistically, with no hierarchy of importance for immersivity to be realised effectively. As an added layer to enhance the depth of this research, it was considered paramount to involve participants and record their responses, because ultimately, their perception as consumers is essential at measuring whether immersivity has been applied successfully [Beeching, 2016, p395].

The ever-expanding use of immersive audio in movie theatres, gaming, home cinemas and even in binaurally mixed recorded songs, demonstrates that there is a growing appetite for immersive music and sound. However, the considerable potential of immersive music performance has yet to be achieved. Whilst there is a general acceptance that it has substantial value (as Smalley illuminates), it remains 'scattered' and 'ununified' [James et al, 2013, p1]. Therefore, a solid framework through academic research is still required, with a clearer definitive vocabulary [Ibid.] which creators can apply with some measure of success. Consequently, the key objective of this research is to establish such a framework for the 'immersive' composer whilst using common vocabulary previously established in the field.

The need to define immersivity in music performance, alongside a methodology that must incorporate composition, performance and space, the following three components were recognised as the key contributors to current gaps in knowledge and practice. Consequently, these also reflect the research questions, with the purpose of addressing the research aim outlined in chapter one.

1. A taxonomy of immersive characteristics.

One of the key aims of this study is to provide a definitive list of characteristics of immersivity in music performance. It was clear from very early on in this study, that the question of what immersivity is in music performance, and what specific characteristics can earn this title, were not definitively established. This has been corroborated by the initial review of reputable literature which while signposting towards some potential characteristics, provided no clear categorisation. Therefore, the objective was to bring together the concrete but fairly scattered theories documented by various authors to form a taxonomy of immersive parameters that can be used effectively in practice and provide some coherence to this performance paradigm.

The five immersive parameters outlined in chapter 7 were deduced from a comprehensive literature review. The list has been constructed by considering parameters highlighted in the literature to employ immersive characteristics that engage more of the audiences' senses [Emmerson, 1993]. The parameters listed - Proximity, Envelopment, Sound Processing, Visual Processing and Audience Engagement - were also influenced by the primary research conducted in section C. The use of a performative practice approach (see chapter 5) has enabled this study to explore immersivity and collect data to deduce the success of the investigative aims, bridging the knowledge offered by previous publications and new research.

As a consequence, it was not until the latter parts of this study that the full list of immersive parameters became clear. For example, Proximity and Envelopment were characteristics recognised early on through a literature review, but it became apparent during initial practice-led projects that neither of those parameters would have their desired effect if sound and visual clarity were not robust. Therefore, Sound Processing and Visual Processing were added as categories in order to include any parameters directly related to the intrinsic cognition of music within a listening space which incorporates visual elements such as physical actions (see chapter 7.4).

The practice-led approach using participant responses, highlighted that Audience Engagement was particularly important regardless of musical style and setting. This was further supported by the literature review elucidated in chapter 7.5. However, it should be emphasised that the significance of Audience Engagement was recognised by participants in this study, rather than by previous papers. Available literature had not made this link explicitly by clearly stating the role of Audience Engagement as an immersive characteristic.

Finally, the list needed further deliberation to ensure that the scope of immersivity was fully captured and presented with clarity and in a logical manner. The goal was to present it in a manner which could be easily understood by professionals, academics and sound-artists wishing to apply this research in their own practice. The author recognises that little in this field is definitive and is also susceptible to change, but this taxonomy presents a solid platform for further post-doctoral research that will likely hypothesise new recommendations and provide possible amendments (chapter 12).

2. *Original compositions specifically designed to critically investigate immersive characteristics within a given performance space.*

There are two important considerations that encompass the purpose of using original compositions to investigate immersivity in music performance. The first is to ensure that the musical style, along with the performance space and the arrangement of the audience and musicians, are appropriate to the investigative needs of each project. This means that each project can be specifically tailored with these aspects in mind for optimum results – an approach which can be identified across all three projects. This approach has been influenced and therefore supported by previous literature on research methodology discussed in chapter 5. For example, project one employed a small acoustic ensemble in an intimate environment, specifically suitable for investigating proximity. The use of three different arrangement methods with three different audiences in the same space, provided a certain level of consistency and reliability, allowing conclusions to be objectively deduced rather than subjectively observed. In project two, the choice of space and the unique arrangement within it were specifically designed with the investigative aims in mind, which were to attempt to balance proximity and envelopment against sound and visual processing. This approach

provided a linear progression that can be observed across projects, each revealing findings through a performative practice methodology. Finally, project three was designed to investigate (to some extent) all of the immersive parameters listed in chapter 7, whilst acknowledging issues which occurred previously.

The second element relates to an audience-centred approach when designing an immersive music performance with specific interest in engaging the listener through the musical material. The literature review discussed in this thesis which outlines the various investigative works in spatial music, observed a common approach - that many of the works were inherently experimental, and employed musical styles that could be broadly expressed as progressive and modernist in nature. From Berlioz, to Ives, Stockhausen and more recently Smalley and Barrett, it is clear that much of spatial and immersive music practice contains composed material that was not aligned with popular music approaches. As stressed across chapters 2 to 4, the absence of popular music practices to form investigations represents a gap in the literature.

The existing literature poses two potential issues with regard to immersive music practice within this study. The first is that the material may lack musical characteristics in line with popular trends that are engaging to the general public; instead, having been designed to be understood and consumed by a broadly expert audience. Inadvertently, this approach is likely to exclude the valuable observations that would naturally occur from a wider range of participants. The perspective of a wider listener base is surely of great value to any study if it is to be more representative of human perception. This leads to the second arising issue in which the largely inaccessible nature of the experimental works means they have been potentially overlooked by the corporate end of the music industry, reflected in its limited consumer appeal.

This music practice is not new, in fact, it has been well established in experimental circles since the early days of *Music Concrete*. With so much time in the making, and conceptually a highly exciting, unique and interesting performance paradigm, it unfortunately remains on the fringes of the music listening world. Of course, this view is affected by technology, resources and facilities which would make such works more plausible in public and private

event spaces. However, these reasons do not negate the important role creators have in making this medium more publicly accessible.

> *"composers...often fruitfully conceive their music following processes, ideas and systems that are not perceptually determined...Regrettably there is too much electroacoustic music that demonstrates a disdain for listeners' indicative needs".* [Smalley, 1996, p.106]

Popular music innovations supported by technology such as Maschine and Ableton Live, together with highly sensory and haptic MIDI devices, continue to advance the possibilities of music performance. The laptop and peripheral instruments are now central to many performances, which along with Bluetooth and Link connectivity, can bring more devices into the performance narrative. This means that conceptually, possibilities are only limited by ideas, resources and budget. Immersive music does have a platform, it just needs to be defined, realised and executed with some success. It would be beneficial to develop a standard in which immersive music practice can be easily produced and transferred so that it can become more accessible to mainstream audiences. As Bates asserts, there will always be a "continued widespread enthusiasm for live performance" and unique experiences [2009, p.4].

A final remark on this segment must highlight the importance of using new and original never-before-heard music for each investigative project - not only to meet the specific investigative needs of each project against the research questions, but also to ensure that audiences have no preconceived notions of how the music should be arranged and performed. This can quickly become problematic with known compositions, which will limit impartiality due to audience expectations.

3. *Participant questionnaire, specifically designed to capture relevant and reliable responses against each project's intended investigative aims.*

It was always the intention to involve participant responses in some capacity, the reasoning being - how can we answer the question of 'immersivity' in music performance without considering the observations of the most important group, the audience? Whilst exploring

spatial works and immersive practice the methods employed were interesting, but the material was not immediately engaging. As a popular music composer, this methodology did not align with the author's own personal approach to composition and live music. It was therefore apparent that an alternative approach to both composition and music engagement was needed.

Rumsey explains that the feeling of immersion is a "psychological state (and) a perceptual phenomenon" [2020, p389]. It is therefore suggested that some may be more susceptible to this feeling than others [ibid. p390]. By measuring the audience's perceived success of particular immersive parameters, this study is able to be more than speculative. This methodology provides a level of objectivity to the research that goes beyond the composer's personal subjective assumptions. The collection of participant responses and therefore the 'audience perspective' play an important role in ascertaining what constitutes immersivity in music performance. This approach was made even more pertinent due to the absence of such a methodology in previous studies surrounding spatial and immersive music practice. The goal therefore, is to expand our current understanding of this field by employing new research methods.

There are some studies that have included participants in this manner to provide insight on immersive music practice in live performance. Some examples discussed in chapter 7 include: 1) Lai et al [2013] in the *'Audience Experience in Sound Performance'* analysed participant responses to determine the effectiveness of the performance (crucially, the authors themselves deduced that the material was far too improvisational with a lack of physical action present); 2) Zhang et all [2016] '*A Web Application For Audience Participation In Live Music Performance'* incorporated phone applications to involve the audience as a collaborator in the performance before completing a survey; and 3) the work of Shirzadian and team [2017] in '*Immersion and Togetherness: How Live Visualization of Audience Engagement Can Enhance Music Events'* employed GSR technology to measure audience engagement through added visuals. Outside of the physical realm, the study *'Evaluating Audience Engagement of an Immersive Performance on a Virtual Stage'* by Kraj and team [2020], examined the effectiveness of the material through the collection of GSR data and self-administered questionnaires. Delving even further into the virtual world, the work of

Andersen et al [2021] used participants to evaluate the effect of individual HRTFs on localisation within 3D virtual environments. These examples demonstrate progress in the use of participants within creatives arts research, but remarkably, it corroborates this study's assertion that such practices are limited within the scope of immersive music performance.

The methodologies listed above are quite specific to their research aims, however, this study used a more holistic approach toward participant contribution to help classify immersivity in music performance. Much of what is known about immersive music from the work of Stockhausen, Austin, Truax and many of their peers, did not employ a participant survey for greater scope, but instead, a discussion of their findings through a personal analysis and dissemination of the performance material. Participants may have not been purposely neglected, but may have reflected limitations due to the era, where current practice has been positively influenced by technologies which make such investigative methods more efficient. So, 1) the need to explain and categorise immersivity in music performance, 2) the use of participants questionnaires specific to each project's investigative needs, and 3) the lack of such an approach in past studies specifically in the investigation of immersive music practice, all demonstrate a novel and valuable contribution to practice in this field.

The use of an audience as research participants has helped to indicate and codify the key immersive parameters that can be investigated further in future studies. There are examples within this paper which present opportunities for further exploration, such as the specific techniques employed to collect information on listening position. In Project Two for example, each audience member had a seat number which they logged into the questionnaire, with the purpose of measuring the effectiveness of the immersive parameters employed in relation to that position. In Project Three, a similar approach was used, where the floor was segmented and audience members were free to roam the performance space as they wished. In both projects, participant responses enabled the collection of data to deduce which listening positions in the performance space were positively or negatively affected by the immersive parameters employed (see chapters 10 and 11 for more detail). It is likely that the methodologies employed in this thesis will be further refined in future post-doctoral research, where I will seek to examine specific immersive parameters from the taxonomy in greater depth.

Section B

Taxonomy of Immersivity in Music Performance

7. Taxonomy of immersivity in music performance

At the core of this research is the perception of *immersivity* within live music performance, which will be briefly summarised before a broader analysis of each immersive parameter is explored. Key questions are: what does immersion mean in the sonic arts; how can we define it within the contexts of live music performance; and how can it be implemented within the compositional process? The definition of immersion could be a thesis within itself, whilst the notion of immersivity is hugely subjective from a listener perspective. Rumsey quotes McHaman, "who suggests that immersion has become an "excessively vague, all-inclusive concept" [2020, p389], a depiction of a model that is in need of much clarification. The aim of this study is to use a literature review combined with an audience centred performative research approach (practice based and led), to ascertain which performance characteristics can deliver immersive qualities. This section will briefly summarise each of the five immersive parameters (as identified by this thesis), before expanding on them for further clarity.

Immersive work is the intention to involve more of the audience's sensors, challenging common listening formats by experimenting with speaker and delivery arrangement within the performance space, and thus make the audience feel they are more connected and *inside* the sound [Emmerson, 1993]. Immersive music can be a medium that surrounds the listener, with greater emphasis on the spatial qualities of the music and the potential of offering a different experience [Moylan, 2012]. The process of surrounding the listener is also defined as 'envelopment', which expresses the level to which the listener feels they are fully immersed in sound [Rumsey, 2012]. Spatial communication in music performance plays a pivotal role in how audiences place meaning in what they see against what they hear. The physical presence and proximity of performers, instruments and sounding sources to audience members greatly influences the musical experience [Henriksen, 2002, p112], by creating an intimacy which in turn makes the sound clearer and larger [Barrett et al, 2018, p403] whilst simultaneously enhancing engagement. The spatial qualities of a performance space and the arrangement of musicians, sounding sources and audiences within it, are uniformly important in the investigation of immersivity. Equally so is the presence of physical action due to our historic and cultural conditioning to expect it [Smalley, 1997, p112].

The literature review presented in this paper represents the knowledge and experience of both academics and sonic artists, whilst audience questionnaires serve to determine the audience perspective against definitions arising from the established literature. Theoretical and scientific approaches provided by experts in this field, have most likely been developed through conventional and practice-based research methodologies, providing this study with contextual conventions to be investigated against. However, the role of the listener, or more importantly the consumer (as we will discover) [Beeching, 2016, p395], must be considered when determining the perceptive characteristics of immersivity in music performance. Although the audience cannot be relied upon as experts, they are the determining factor in the success of a work. Their opinion when gathered through traditional research means (qualitative and quantitative) will be of a great value to this study, and will take place in the form of primary research through original projects. As Beeching [2016, p395] convincingly proposes - that during the development of art-works for the enjoyment of audiences, an audience-centred approach is required if the product is to be successful and sustainable.

The following taxonomy of five immersive parameters has been proposed from the secondary research conducted in the form of a literature review. These parameters have been further informed and influenced by primary research conducted through performative practice, which has investigated the potential of these parameters to create an immersive music environment through a series of original works discussed in Section C.

Proximity

- *The proximity of a listener to sounding sources.*

This category refers to the proximity of the listener to any *sounding sources*, where a sounding source includes all performing musicians and any speakers that reproduce sound. The listener's closeness to the sound develops *intimacy* and *inclusion*, which might then produce meaningful characteristics from the audience and performers perspective; something Henriksen calls "spatial communication" [2002, p.112]. The sense of "closeness and involvement with a performance" can help to improve emotional connection to the music

and performance, most likely due to our ability to "discern detail" [Cabrera et al, 2004, p1]. Inversely, the further we are from sounding sources, the more disconnected or detached we may feel from it [Ibid.] - as can be experienced in very large performance spaces where the segregation between performers and audience is augmented [Austin, 2000]. Harries [2011, p108] expresses this segregation as *territorial behaviour* and it is crucial to how music performance is perceived.

Envelopment

- *The practice of surrounding the listener with sound.*

The term envelopment refers to the experience of sound fully surrounding the listener, both on the horizontal and vertical plane, otherwise known as the 3D audio environment, which is how we naturally hear any space we are in [Barreiro, 2010]. The term *space* can also be referred to as the *soundfield*, i.e., the space in which sound energy is being dispersed. The aim is to make the audience feel that they are inside the sound [Emmerson, 2007, p.155], a definition usually applied to immersive works. In some instances, it is possible to fully immerse the audience in a manner in which the sound-image is not compromised by their listening position [Smalley, 2007, p52]. Hence, the immersive nature of a work can be increased by employing methods where sound emanates from multiple points within the performance space, such as through the use of in-the-round seating or surround-sound loudspeaker systems. In simple terms, envelopment is determined by the sound emanating directly from sound sources plus the inherent reverberation characteristics due to the room's acoustic properties [Lee, 2013, p1].

Sound Processing

Two key parameters have been identified in the investigation of sound processing –

- *Sonic Clarity refers to the listeners ability to accurately hear sound sources and differentiate timbres within a performance space depending on their position.*

- *Localisation refers to the listeners ability to distinguish the position of a sound source and any movement of it within the soundfield.*

This study has thus far revealed that the performance must inherently delivery high-quality sonic clarity before any additional immersive elements can have their intended impact, where the reduction of sound quality directly relates to the listeners reduction of enjoyment. As Moylan highlights [2012], spatial characteristics can provide important sonic clarity, but Harley [1998, p150] reminds us of the issues that can exist in spatially-oriented music, such as unequal listening positions and performance coordination errors. It is a fundamental challenge of immersive works, where experimental arrangements of the audience and sounding sources within a given performance space, designed to increase proximity and envelopment, can negatively impact sonic clarity.

Localisation is a central feature of our hearing capacity, allowing the listener to accurately distinguish where a sound has emanated from and its direction of movement [Roginska et al, 2017, ch1]. Take for example the singing of a bird or the sonic trajectory of a siren. The practice of this natural characteristic as a technique within music performance can be a powerful tool, where a composer might choose to increase the immersive nature of a work by employing sounds that move within the soundfield adding "physicality and dynamism" to a performance [Bates, 2009, p.4]. The term *spatialisation* refers to the technique used by a composer in which "spatial projection, sound location and direction", become important elements in the music, [Harley, 1999, p148] - whether from a walking musician or the movement of a sound-source within a sound reproduction system.

Visual Processing

- *Our ability to visually process any physical actions and movements of sound sources within the performance space*

The ability for audiences to clearly see and construct musical meaning from any physical action such as playing, singing and moving, is a visual element of great importance to any live performance [Wright, 2010, p6]. Physical actions are important elements in music

performance because we make connections between the actions of a musician and the sound that is heard [Smalley, 1996, p84]. We intuitively create relationships between what we hear and what we see to help us understand the real-world, also known as 'source-bonding' [Smalley, 1997, p110]. Take for example how we recognise the different sounds animals make - we can apply this same principle to the sound produced by instruments.

Parmar [2012, p208] explains that when we hear sound in a composition, we use our memory to relate what we have heard to any known sounds we have previously encountered in the real world, we do this on an auditory and visual level by processing the sound and then imagining the sound sources. This natural instinct becomes problematic in certain forms of music performance, such as acousmatic works and laptop music, where physical actions such as 'gesture' and 'utterance' have been removed or reduced (due to the processing sound sources and their movement through visual means) - this quandary is at the centre of this study's research aims and the experimentation employed in Project 3 (chapter 11).

Audience Engagement

- *To engage the audience directly in the performance.*

Whether singing with friends at home, in a venue, or with thousands of strangers in a stadium, an emotional connection can be produced through the act of sharing. When an audience is being engaged it arouses emotions, stimulates physical reactions, taps into memories and fantasies, and triggers a cognitive response [Radbourne et al, 2009, p18]. We can determine that a listener is fully immersed in the entertainment being offered when they lose awareness of time, delivering a momentary escape from the real world [Shirzadian et al, 2017, p5]. Through this study's questionnaires a large percentage of participants indicated that audience engagement is perceived as an integral feature of immersivity in performance. This is unsurprising considering the success many artists have had in engaging audiences by including them in the performance narrative.

Immersive theatre productions have for some time engaged their audiences on this level with great success, reframing how performers, the physical space and audience engage with one

another. The audience is a consumer after all, and any successful performance practice must therefore consider an audience centred approach [Beeching, 2016, p395]. This may include positive aspects of interaction and methods to captivate the user [Shirzadian et al. 2017, p4]. Audience engagement is multifaceted, which requires an awareness of the listeners wants and needs in order to shape products that meet their expectations, and not relegate them to merely receiving participants [Zhang et al, 2016, p1].

7.1 - Proximity

Seats at the front of a concert hall are usually the most prestigious and costly, whilst gig and festival goers will happily camp for an extended period to be at front and centre. This demonstrates that proximity is one of the most sought-after characteristics in any given performance space. So why is the proximity to performers held with such high regard?

Emmerson [2007, p155] explains that proximity can make the audience feel they are more connected to the sound and musical content. Henriksen [2002, p.121] discusses intimacy, where audience and performers are arranged in a way in which one can "sense body heat and/or cannot avoid contact, may increase listeners' receptivity to intimacy in the music". There is a connection with the performance that happens beyond listening and falls into the physical realm. The sense of intimacy here arises when the audience is able to connect physically and emotionally to the performer, one such connection is the proximity to sound sources, such as the physical presence of the instrument, voice or loudspeaker reproduction system. By being close to the performer, we can feel the power of their instrument and immediacy of their motions. Closeness can be understood spatially (physical proximity) and temporally (happening right now), whilst immediacy can imply "being involved at some level" [Popp, 2014, p9]. The meaning of the projected sound can be decoded much quicker, whilst the proximate nature ensures better fidelity of the sound, which includes attack and tone before it is coloured by the reverberant space. Proximity forms an entry-point for the listener to the performed material, and hence can increase engagement [ibid.]. In addition to timbral detail, proximity allows us to perceive sounds as 'larger' [Barrett et all, 2018, p403]. The visual

aspect of proximity additionally helps audiences understand or give meaning to performance characteristics (see chapter 7.4), whilst also enhancing localization (see chapter 7.3).

Audience enjoyment of a live music performance is heavily influenced by the seating plan, or the boundaries of the sonic space we are able to explore. As Blesser et al [2005, p6] explain, "we function as aural architects when we select a seat… or position loudspeakers" and this is no surprise as our ears have the ability to "perceive with impressive accuracy the spatial location and motion of a sound source" [Zea, 2012, p.1]. Therefore, the arrangement of audience and performers, as well as the social rules within the concert space are very important [Henriksen, 2002, p119]. Harries [2011, 107] explains that an individual's relative position to the sounding material is crucial for human interaction and influences communication. It is unsurprising therefore that spatial communication can be enhanced through proximity.

> *"How close or far away we are from each other, whether we stand higher or lower from another person, and the direction in which we move away or towards one another can all convey important messages. In performance, there is spatial interaction between the performer and the audience, between the performers on stage, and sometimes between members of the audience."*
>
> Harries [2011, 107]

Harries coins the term 'spatial behaviour' to include proximity, orientation, height and territorial behaviour as parameters to explain spatial communication in music performance [ibid]. He defines these as:

Proximity – different types of interaction relative to ranges in distance between subjects [ibid]

Orientation – the angle at which musicians and audiences engage with each other, which may change over the course of a performance [ibid, p108]

Height – determines the elevation relationship between the performers and audience. A stage may induce a level of authority to the performer and deem the audience as submissive [ibid]

Territorial behaviour – the division between audiences and performers which is crucial on how a performance is perceived [ibid]

Proximity as a compositional tool however, can be dependent on musical style [Smalley, 2007, p42]. A large orchestra and choir may sound better from a distance, in which the power of the collective sound is more balanced and connected (less detached and disparate), whilst it is likely to benefit from the reverberant colouration of a larger space. A small folk group however, may be more suited to a small intimate performance environment, in which the independent gestures of musicians can be better appreciated. Popp [2014, p63] explains that sounds connected to human activity (gesture) are key to expressing closeness and immediacy. It is not difficult to assume from our own experiences that proximity (distance to sound sources), is an integral element in the way audience members perceive a musical performance from an audio-visual (not social) perspective. Take for example the differences when watching the same performance at the front of a small venue as opposed to the back of a large open-air festival. Therefore, composers should consider not only the type of performance space, but also the appropriateness of the compositional material for that particular space during the creative process [Popp, 2014, p12].

There are various commercial examples in which proximity has been applied to good effect, such as in immersive theatre. The immersive Wolf of Wallstreet is just one such example, in which performance spaces are designed to reflect living spaces in any home, with audience members scattered within them to bring the audience much closer to the action. Sofar Sounds concerts employ a similar approach, in which concerts are held in intimate home or workspaces with (usually) no amplification, ensuring musicians and audiences engage directly with each other on a physical level. There are also examples in the studio, in which ensembles such as Snarky Puppy invite fans to sit among the musicians whilst material is recorded live, to deliver the rawness and intimacy of a live concert but in the studio. The emotional and physical presence developed by the combination of the band, their loyal fan-base and the recorded material, stimulates a temporal energy and deep connection to the material which could not be captured otherwise, and ultimately, effects the recording positively.

The positive effects of proximity mentioned above can be reduced when concert spaces become larger and therefore distance between listener and sound sources increase. The larger the space means that some audience members are more likely to be further away from sounding objects, which can create an imbalanced sonic image, and in acoustic pieces that do

not employ a loudspeaker reproduction system, this can impact loudness and reduce intimacy [Austin, 2000, p12].

> *"you lose intimacy in a larger space, and that's important. You are no longer so close to the sound, you no longer hear the details. The other elements are the size of the image, the breadth of the image, and the depth of the image."* [ibid, p14]

More importantly, there is the loss of detail in the timbral architecture of the instrument and voice as well as the timbral characteristics inherent in a performance delivery [Ibid., p14]. The traditional front-back performance model creates an unseen separation between the performed musical content and the listening consumer (what we explored already as 'territorial behaviour'). This separation paradigm is further exaggerated as performance spaces increase in size, where a physical and tangible artform is transformed into a remote and ethereal experience. In this case, the spectacle changes from the intimate to the grand, and therefore begins to reduce the level of immersion produced by proximity. The tradition of placing speakers on and to the side of the stage in a stereophonic fashion, further strengthen the sensation of separation, however, by surrounding the listener with sounding sources a more immersive listening situation can occur [Harries, 2011, p109]. We may wish to use a large festival space as an example, in which listeners at the very far edges tend to consume the music aurally from distant speakers and visually on screens. We may consider this separation as a reduction in inclusivity, and therefore relegate such audience members to peripheral listeners. Consequently, those listeners may not be fully engaged in the performance as much as those closer to the stage, who can yield a greater influence on the musicians and therefore the performance.

> *"the physical proximity to the sound field and the encouragement or discouragement of personal interaction in the listening situation are all factors related to spatial communication, that are influential on the musical experience*" [Henriksen, 2002, p112]

However, Harries [2011, p107] asserts that as long as the gesture is amplified through mediated means (projections), the sense of intimacy or at least the impression of intimacy from afar can be preserved. The emotional connection arises from the collective mood created within the performance space, through the delivery of material by the musicians and

how audiences engage with that material and each other. When the performer connects emotionally to the material, so does the audience, which influences the performers, who respond and encourage the audience further. Kendall [2010, p229] explains that listeners experience sonic events as 'intrinsically spatial' because they take place in space. He further highlights Rumsey's assertions which propose the following spatial attributes [ibid, p230]

Dimensional Attributes

- *Direction*
- *Distance*
- *Depth, Width & Height*

Immersive Attributes

- *Presence (inside the performance space)*
- *Envelopment (surrounded by sound)*

The physical space of a performance is established by the physical presence of a live performer [Harries, 2011, p88]. Harries goes on to assert that the human presence in a live performance environment encourages the audience to acknowledge the physical space [ibid]. This assessment can be applied regardless of the size of the performance space, and when that physical presence is evaluated against Rumsey's *dimensional* and *immersive* attributes, it can determine whether proximity has been enhanced enough to create an intimate environment from each listeners perspective. Therefore, the size of the performance space, as well as the arrangement of the performers, sound sources and audience within it, are integral parameters to be considered when planning an immersive performance environment.

To summarise, the employment of proximity in a musical performance is a form of spatial communication that can produce an intimate and inclusive environment, and which is therefore able to enhance emotional connection to the material on a temporal level due to heighted localization, physical presence and timbral clarity. Thus, proximity demonstrates that on a physical and emotional level, it can enrich the immersive performance experience. The experimental investigations conducted in this study will further reveal its importance.

> *"People have come especially for the performance; in order to create a rewarding experience, you have to provide something more than what is possible when listening at home."* [Austin, 2000, p11]

7.2 - Envelopment

The term *envelopment* is significant in the study of immersivity and refers to sound being heard from "all around the listener, with no definable point source" [Ainlay et al, 2004, p2.1]. Envelopment is achieved by placing the listener at the centre of the 3D sound environment [Barrett, 2010, p8]. Envelopment is a more accurate term for the sensation of being *surrounded* by sound, or immersed by sound in an enveloping space, which is exactly how we hear in any given soundfield (the 3-dimensional aural environment) [Barreiro, 2010].

> *"The world is performing a constantly unfolding, naturally occurring composition, of which we are all part: we just have to listen"* [Barnard, 2010, p6]

Delivering surround-sound using technological means has become a staple in cinema, some home settings, and even appearing in cars [Ainlay et al, 2004, p2.1], meaning that consumers are becoming more accustomed to listening to mediated music in surround sound formats. Commonly, we may think of 5.1 as a surround sound system, but we must highlight the difference between that and a fully enveloping sound space. The former can simply imply surrounding the listener with sound on the horizontal plane, but the latter also includes the vertical plane for a truly immersive 3D environment. Smalley [2007, p52] categorises immersivity as a space filled with sound, in which the surrounding sound of one's *egocentric space* (the space within arm's length) is not dominated by any single direction, meaning that localisation is not compromised and therefore a listener may enjoy different vantage points (different listening positions within the performance space). Ideally, in a fully immersive sound-space in which the listener is fully enveloped by sound (as we are in the real-world), any vantage points would not affect the quality of the sound-image - Ambisonics is a fairly effective technique at achieving this, but large loudspeaker arrays are required.

Many studies have been completed to examine the characteristics of envelopment within sound spaces. Envelopment is determined by *apparent source width* (ASW) and *listener envelopment* (LEV) [Adair et al, 2008, p1], although Cabrera [2006, p1] also includes *intimacy*.

> *"ASW can be defined as "the perceived width of a sound image fused temporally and spatially with the direct sound image" whereas LEV as "the perceived impression of being surrounded by the reverberant soundfield. It is generally agreed in the literature that ASW is related to early reflections arriving at the listener's ear within 80ms after the direct sound, while LEV is regarded as a property of reverberation arriving after 80ms."* *[Lee, 2019, p1]*

Cabrera [2006, p1] explains ASW as the feeling of "spaciousness, which is affected by the auditorium environment and the auditory image size of a musical performance", whilst LEV is the feeling of being surrounded by the reverberant field. Our sense of envelopment is therefore influenced by the "level, direction of arrival, and the temporal distribution of later arriving reflections" [Bradley et al, 1995, p2596].

ASW and LEV are affected by the reflections of spatial structures [Morimoto et al, 2007, p1611]. The characteristics of any given spatial structure such as a concert hall will have an impact on the room's acoustics, and therefore an impact on how we may perceive envelopment within that space [Adair et al, 2008, p1]. Smaller spaces for example will produce both "louder and more enveloping dynamics" [Lokki et al, 2020, p2144]. Furthermore, this means the listener's subjective response to the enveloping sound may be determined by their location within that space [Adair et al, 2008, p1]. It is difficult to create a satisfactory image for listeners at the front and back of a long rectangular hall for example [Austin, 2000, p12]. Morimoto and team [2007, p1615] explain that reverberation time (RT) effects both ASW and LEV, where low frequency RT affects ASW, whilst LEV is affected by both low and high frequency RT. Additionally, longer RT will increase LEV [ibid.]

Although there has been significant research undertaken in the field of envelopment, it remains difficult for the composer to create any level of envelopment control within a given space due to the various factors that affect it, such as:

1) the size of the space and its structural composition,
2) the size and amplitude level of the ensemble and/or speaker-array along with their position within the space, and
3) the placement of the listener and closeness to the sounding sources.

All of these factors will determine the success of an enveloping sound-space, something the composer can consider and apply during the creative process. It remains difficult however, to know how the sound will react until it is performed. As Cabrera [2006, p1] explains, although ASW, LEV and intimacy provide context, they "scarcely account for the variety of impressions available in spatial hearing".

It has been established that listener perception with regard to position within a performance space effects levels of envelopment. Smalley [2007, p55] provides three categories that supports our understanding of the sonic image within a soundfield:

1. *Prospective Space:* The frontal image within our range of vision
2. *Circumspace*: The space around the listener
3. *Panoramic Space:* The sonic image at the limits of our peripheral vision

Prospective Space may therefore explain the sound-image as perceived in traditional front-back performance models, whilst Circumspace and Panoramic Space can help illustrate the perceived sound in an immersive performance environment. Natasha Barrett refers to the Berg et al. assessment of listener envelopment that makes a distinction between two categories, 1) 'room envelopment', in which we feel surrounded by reflective sounds; and 2) 'source envelopment', in which we feel surrounded by sound sources, such as instruments or loudspeakers [Barrett, 2010, p7.]. Barrett attempts to distinguish between envelopment and immersivity, in which "immersion is directionally less defined", unlike envelopment which contains directional cues [Ibid.].

Visual envelopment which is a natural feature of our visual world, plays a significant role in our understanding of auditory envelopment, as we naturally associate what we hear with what we see. It can be argued however that the reduction of visual characteristics (a darkened room for example) can increase our sense of sound immersion [Cabrera et al, 2006, p2]. Visual

and auditory intimacy decreases with distance, as does our ability to determine detail diminishes [ibid., p6].

As listener perception is integral to the delivery of sound envelopment, localisation and spatialisation tend to be key characteristics of spatial music. Human hearing has an ability to determine a sound source within a soundfield and its direction of movement (if any), called *localisation* [Ainlay et al, 2004, p2.1]. Some composers may wish to take advantage of this ability, by purposely making sound objects move across the soundfield during a performance; this is a technique called *spatialisation*.

As envelopment is such a "desirable characteristic" of a space, continuing research might facilitate the design of spaces that can "optimize visual and auditory envelopment" [Cabrera et al, 2004, p7]. Karlheinz Stockhausen had his own ideas of what a perfect performance space would be for spatial music, cementing the idea of enveloping sound.

> *"New halls for listening must be built to meet with demands for spatial music. My idea would be to have a spherical chamber, fitted all round with loudspeakers. In the middle of this spherical chamber a platform, transparent to both light and sound, would be hung for the listeners. They could hear music, composed for such adapted halls, coming from above, from below and from all directions"* [Stockhausen, 1959, p.69]

The continuing study and practice of envelopment within academic research and industry development, demonstrates that this is an integral characteristic from an auditory perspective. The pursuit of surrounding the user with sound in a manner the emulates the real world is playing a pivotal role in many consumer markets, including theatre, cinema, gaming and music. Its importance as an immersive characteristic has been investigated in all three original projects conducted in this study by using innovative delivery formats, which have yielded positive responses. This parameter has therefore been established as an immersive characteristic for some time, and continues to be a growing trend – one which is continually supported by developments in technology. With regard to production, much of this is owed to computer applications which have made the production of immersive audio products more practical, for both loudspeaker systems, soundbars and headphones. End-user devices such as mobile phones, tablets, laptops and video-game consoles in combination with

streaming and broadcasting services, as well as Bluetooth and WIFI connectivity, have made such products far more accessible.

7.3 - Sound Processing

Listening & Perception

Audience perception of a musical work is integral to its success. There has been research undertaken in this field which focuses on "discovering associations between the music and (the) emotions" perceived [Camci, 2012, p2]. This study has included audience perception as an integral element in deciphering the success of the musical work in relation to its intent on creating an immersive environment. Without audience responses, any assumptions made to the effectiveness of the techniques employed would be simply speculative. Audience perspective of a musical work is highly subjective, and as Barrett [2018, p400] argues, responses can be "notoriously inconsistent". Nonetheless, responses have been vital to this research in discovering what constitutes an immersive music performance environment, and have thus far provided very practical evidence.

Various listening modes have been established to describe how listeners consume audio events differently. Hewitt [2006, p7] presents us with three such types of listening modes:
1) "*Causal* – listening to a sound in order to gather information about its cause or source.
2) *Semantic* – listening to a code or a language to interpret a message, e.g. spoken language or codes
3) *Reduced* – a listening mode that focuses on the traits of the sound in itself, independent of its cause and meaning" (first termed by Pierre Schaffer).

These modes are tightly linked to the level of prior experience each listener has with the musical medium and their ability to apprehend artistic meaning [Kendall, 2010, p228]. Truax [2008, p107] explains that 'distracted listening' is a form of unfocused listening that perceives music as part of the environment, whilst 'analytical listening' is the ability to discern qualities in the sound. 'Technological listening' is when a trained individual is able to decipher the techniques that lie behind the sound and music [Smalley, 1997, p109]. Smalley argues that

this may inhibit the listener from the music's "true meaning" [Ibid.]. He further explains that hearing and listening are inherently different:

> *"To 'hear" implies an Involuntary act, that a sound penetrates consciousness, almost that one cannot help hearing, whereas to 'listen' signifies an intention on the part of the listener who consciously apprehends a sound."*
>
> [Smalley 1996, p78]

This idea of types of listeners and their overall experience to perceive the work as it was intended is a difficult concept, and one which composers and performers may wish to question. Do we wish our audience to be entertained naturally through the presence of melody, harmony and rhythm, or do we expect our listeners to be engaged in our journey willingly, whether they are aware of it or not?

> *"There is a type of auditor who will not meet the performers halfway by projecting himself, …, into the premises as best he can, and who will furnish nothing more than a ticket and a receptive inertia which may be induced by the predilections or static ear habits.... Some hearers of the latter type seem to require … constantly something desirable … which may be called a kind of ear-easing …; if they get it, they put the music down as beautiful; if they don't …, they put it down (as) bad, ugly or "awful from beginning to end." It may or may not be all of this, but whatever it is will not be for the reason given by the man who doesn't listen to what he hears."* [Johnson, 2002, p220]

The way in which composers create musical content is unlikely to be similar to the way in which audiences will perceive that same music [Smalley, 1997, p1]. Composers therefore may wish to consider the listening experience of their audience when they create works. For example, does the audience have the experience to actively engage with the auditory information of a piece, and is this at all important? Wright [2010, p44] tells us that each listener has predetermined coded cultural and social norms, as well as expectations that will deem a performance as a success or failure. This is the case across the arts, in which audiences are entitled to be critical of an artwork based on their personal wants and needs. This becomes even more pertinent in the performance of experimental spatial works, in which listener expertise may vary dramatically and will most likely be limited. A composer might misjudge the strategy in which sound-based material is communicated to an audience which may lead to the work being misunderstood [Truax, 2012, p13].

John Cage's famous work *'4:33'* suggested that there is a lot more to listening than was previously thought, that there is also music naturally occurring in the performance space if we only just listen [Truax, 2012, p1]. We sometimes close our eyes when we listen to music, not because we do not want to see, but so we can focus on what is not visible [Ceasar, 1992, p17]. We can do this when we hear music through a HiFi system, headphones or at a concert, allowing us to concentrate on what we are listening to.

There is an argument whether a visual presence inhibits the listener from being truly immersed in the sound or whether it adds a necessary cognitive layer. Smalley [1996, p103] argues that any visual component drags the music into the gesture field and relegates the acousmatic work into a subordinate role. Barrett [2018, p400] agrees that it is best if "visual information is removed so as to free the listening imagination and prevent the eye dictating how we will hear". Any acousmatic work can only be fully acousmatic if all other elements are removed, so that the music performs in the same manner as it does in the recorded format [Smalley, 1996, p104]. This may be an informed assessment for the acousmatic medium, but in other types of electroacoustic music that contain performers, listeners will naturally connect meaning to the physical gestures and the sound heard. Therefore, audience perception will naturally relate to the physical cues presented by the performers.

We are conditioned to listen to sounds and relate them to previous experiences. This is an enate programming that we use in the real world, whether it is the singing of a bird or the siren of a speeding vehicle. We also put this into practice when we listen to sound emanating from an instrument or loudspeaker, which we try to codify against pre-existing "cultural and/or environmental contexts" to add meaning [Hewitt, 2006, p7]. Truax [2012, p2] explains that sound creates both personal and social relationships as a flow of information between listeners and their environment, which he terms as '*acoustic communication'*.

> *"The feelings and thoughts that the listener associates with the experience of sound in space appear to arise from a deeply embodied knowledge of space and spatial movement."* [Kendall, 2010, p228]

Harries highlights that live performances are typically interactive environments because listeners can choose what to observe at any given moment, regardless of whether their position is fixed or not [2011, p132].

The various factors discussed thus far, which contribute to audience perception of a music event, may well need to be considered by creators. Stansbie [2010, p21] adds some further contributing factors:

- The type of sound playback system
- The specific configuration and colouration of the loudspeakers
- The acoustic influence of the concert hall or listening space
- The position of the audience
- The perceptual experiences of the listeners

Although he made these comments in reference to acousmatic music, these are relevant to most performances of electroacoustic music that may or may not contain a performer. It is true that the performance space itself can influence how the audience will perceive the work, thus the composer must consider the space at both the composition and performance stages [Dow, 2005, p1].

The chapter has highlighted that the manner in which an audience listens and perceives music works is incredibly complex, and entails various personal and environmental factors that are subjective and vary depending on the experiences of the individual. Nonetheless, the gap in research practice outlined in chapter 6 with regard to audience participants as a form of primary research, means that this is an avenue this study has actively pursued. This had already been considered as an essential research aim before the gap in practice had been recognised. Further research has demonstrated that it is possible to obtain reliable and relevant data from participants through well designed questionnaires that can inform this study against its investigative aims (chapter 5.2). The aspect of listener perception however, must also consider audience engagement, which will be explored in chapter 7.5.

Space

Beyond the listening domain, composers also need to consider the space in which the work is performed. The space cannot be separated from the music, and has an intrinsic effect on the musical material. Harries considers the size, location, the receptacle, its borders and the aural perception of space as all inherent physical attributes of a performance space [2011, p76].

> *"When "a piece is played in another room, many aspects of the sound are subject to the acoustic qualities of that room and the numerous varied positions of the audience members. Spatial details become unclear; the effect of dynamic range is reduced by reverberation, background noise, and other factors; and subtle timbral relationships can be severely affected"* [MacDonald, 1995, p90]

We are very aware of the performance space, because as Smalley explains "we are constantly aware of personal space within the orbit of our practical daily activities or personal relations" [Smalley, 1996, p91]. The acoustics of a performance environment have an enormous effect on the perception of a musical work [Dow, 2004, p1]. A space itself has its own sonic qualities which cannot be removed [Smalley, 1996, p91], therefore a space which contains music is a musical space, "where one has limited power to control (it)" [Austin, 2000, p14]. Harries argues that the physical attributes of the building and its environment produce a "secondary performance of their own" [2011, p73]. Dennis Smalley [1996, p91] provides three distinctions of the musical space:

1. Space as an enhancement or reinforcement of sound,
2. The articulation of the composed content,
3. The interpretation of space on how the listener experiences and feels about space.

Composers often write music in isolation, usually in a studio which is inherently different sonically than the space in which the work will be performed [Stansbie, 2013, p38]. This is the case in both instrumental and acousmatic performances. Loudspeakers in the concert space are highly unlikely to reflect the conditions (the position and room ambience) of the studio the work was composed in [Ibid.]. Furthermore, the placement of the speakers further away from the listener, the more the space's acoustics will interfere with the sonic qualities of the work [Harrison, 1998, p124]. Larry Austin clarifies that the natural reverberation of the space

should be considered during the performance of an acousmatic work, because if we apply reverb in pre-production, we are essentially creating an ambience within an ambience [2000, p16].

There are opportunities to mitigate the effect of the sounding space during rehearsals by making appropriate adjustments in balance and placement. However, the presence of an audience means that the sounding space behaves differently during a concert [Harrison, 1998, p126]. Any adjustments, or as Stansbie describes, 'interpretative decisions' during rehearsals are speculative, and will most likely require further adjustments during the performance [Stansbie, 2013, p132]. He goes on to explain that it is important to listen from various different positions that audience members might occupy when making adjustments prior to a concert [Ibid., p131]. These adjustments however may likely be academic and ineffective, due to the fact that neither musicians or conductors are able to hear what individual audience members hear during the performance, or as Smalley candidly explains, the "ultimate spatial setting, … usually lies outside the composer's control" [1996, p91].

In sound diffusion a performer may employ various tactics to mitigate the influence of the sounding space on the work, or alternatively embrace the conditions because as Stansbie summarises from Harrisons comments - "it is the medium which is fixed, not the music" [Stansbie, 2013, p31].

> *"It seems to me that the best approach to performing electroacoustic music in public spaces is not to deny the characteristics of the space in an attempt to recreate the sound as heard in the composer's studio, but to use those characteristics as part of the listening experience"* [Harrison, 1998, p124]

Truax [2012, p5] explains that even "the most exquisite sound sculpture will not function well in a noise-ridden environment where people do not listen attentively", therefore, the environment of the space the music is performed in is integral to how it is perceived by the audience. Imagine a work that is influenced by the performance space rather than one that is adapted to it [Ibid, p8]. Imagine if sounds weren't simply added to the environment, but instead interwoven with the already existing spatial qualities of that space [Ibid, p5]. Kendall

[2010, p233] argues that the room and loudspeakers could be treated as a vehicle to create sound spaces, rather than using them as the space in which they are projected.

> *"For instance, what kind of music would work best in an abandoned factory or on the shore of a lake, and how could it interact with that specific acoustic situation? What if the piece took on a theatrical element by being designed for a specifically gendered performer with certain acting skills? What if the piece were designed to be performed only at a specific time or special event?"*
>
> [Truax, 2012, p8]

It may be impractical, especially from a commercial sense, but it is a goal that we could pursue as creators. In fact, we might need to rethink the process, so that we create with the space in mind rather than in studio conditions. By doing so we can tailor music to that specific environment, free from conceptual constraints [Ibid, p9]. This however, is an entirely different compositional skill-set, one that fully understands and appreciates the spatial characteristics of a room.

Smalley [2007, p41] categorises the performance space relative to the audience into the *intimate*, *personal*, *social*, and *public*:

Gestural Space – This is the *intimate* space of a performer and instrument [Ibid.]
Ensemble Space – This is the *personal* and *social* space of ensemble performers [Ibid, p42]
Arena Space – This is the *public* space that inhabits the ensemble and audience [ibid.]

He also provides categorisation of spaces:

Panoramic Space – the frontal image that extends to the full range of vision [ibid, p48]
Circumspace – the full sonic space around the listener [ibid] (similar to envelopment)
Egocentric space - the personal space surrounding a listener (within arm's length) [ibid, p55],
Immersive space - where the listener feels immersed in the spectral image [ibid.]

Then there is of course the arrangement of the performers and audience within a given space. Harries [2011, p77] discusses various arrangement formats presented by Xenakis and demonstrated graphically in figure 7.1.

• *Frontal* – a typical stage situation with a clear division border between the performers and audience
• *Central* – an in-the-round formation where the audience is situated around the performers
• *Sources surrounding the audience* – a common surround sound setting
• *Sources within the audience* – scattered sound sources including musicians within the audience
• *A narrow or lineal performance space* – as in a procession or parade
• *A hybrid of several of these types*

The perception and effectiveness of any performance piece can be said to relate to the listeners *vantage point* within a space [Smalley, 2007, p35]. A listeners vantage point can be explained as the position in which an individual receives the auditory image [ibid, p42]. Smalley describes the vantage points as *fixed* (seated), *variable* (changeable) and *peripatetic* (more than one listening space) [ibid, p52]. If an audience member is not constrained to a single position and given the opportunity to explore the performance space freely, it may lead to a stronger spatial perception [Klein, 2009, p101]. This is because the listener is allowed to take an active involvement on how they experience the space and spatialisation of that piece [Harries, 2011, p97]. Hence, the encouragement to freely explore the space is likely to trigger active engagement [ibid, p132].

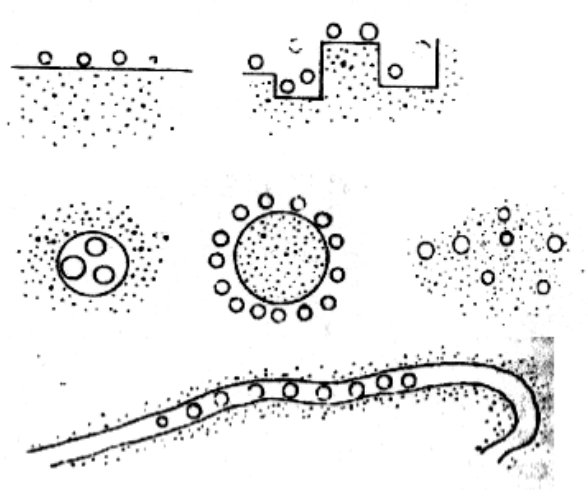


Figure 7.1 – graphic description of Xenakis's arrangement types
[Harries, 2011, p78]

Listening position is vitally important in the way the sound image is perceived [Kendall, 2010, p228]. Kendall goes on to discuss that all movement, that of the body, objects and other

people, allow us to understand space and spatial behaviours [ibid, p232]. In most cases, an individual's vantage point is usually fixed, unable to explore other listening possibilities. In addition, distance also plays a key factor in our auditory perception. Studies have revealed that listeners often mistake the true physical distance of a sound source, with results showing that long distances are underestimated, whilst close distances are overestimated [Zahoric, 2002, p1844]. Zahoric [ibid, p1832] proposes the following acoustic distance cues in which both the listener and sound sources are stationary:

- *"Intensity* – sound intensity at the listener's position decreases when the distance between (the) listener and sound source is increased… this … depends on both (the) environmental characteristics and various properties of the sound source [Ibid.]

- *Direct-to-reverberant energy ratio* - reverberant energy is determined principally by the size of the room and the acoustic properties of (its) reflecting surfaces [Ibid.]

- *Spectrum* - for distances greater than approximately 15m, the sound-absorbing properties of air significantly modify the sound source" [ibid, p1833]

The points made above by Zahoric help to justify why proximity is such a valuable listening asset in the process of observing and decoding audio content in live performance. If we consider that even single tones can carry multiple tonal characteristics, such as brightness, fullness, dullness etc. [Koelsch et al, 2005, p578], these simple musical elements are further transformed depending on the performance space and the position of the listener. In addition to this, the perception of sound in a space is further affected by the speed, shape and regularity of its movement [MacDonald, 1995, p90]. This means that independent and collective sounds carry auditory information to be emotionally interpreted by the listener. Smalley [1997, p1] has coined the term '*spectromorphology'* to describe these aural phenomena – '*spectro'* meaning the interaction between sound spectra, and '*morphology'* being our understanding (interpretation) of how these are changed and shaped through time [ibid.]

To summarise, the perception of sound in any given space is incredibly complex and multifaceted, but ultimately can be encompassed within four specific spatial factors:

1) the size and shape of the performance space,
2) the suitability to the musical material for that space,
3) the arrangement of sound sources within it, including spatialisation techniques, and
4) the arrangement of audience members within it, including the potential of varying vantage points.

All of these factors have been carefully considered during the development and design of each original project, and go some way to help this study investigate research question 2 (chapter 1).

Localisation & Spatialisation

Localisation refers to the listeners ability to distinguish the position of a sound source and any movement of it within the soundfield, including multiple sources simultaneously [Roginska et al, 2017, ch1]. The location of a source can be specified using *azimuth*, *elevation* and *distance*, in which 0° is the azimuth and elevation of facing directly forward [ibid.]. The azimuth is categorised as 90° directly to the right and -90° directly to the left. Similarly, elevation uses positive and negative prefixes for above and below respectively. Examples of these can be seen using the DearVR spatialisation plugin in figures 7.2 & 7.3 below. The distance is measured in meters.

Figure 7.2: +90° azimuth and elevation

Figure 7.3: -90° azimuth and elevation

Localisation on the horizontal plane results due to the manner in which we process Interaural Time Differences (ITDs), measured by the time difference the signal arrives at each ear; and

Interaural Intensity Differences (IIDs), measured by the intensity (or loudness) difference at each ear [ibid.].

In example A (figure 7.4) the azimuth is at 0°, and therefore the signal will arrive at each ear simultaneously. In example B, azimuth is at +60°, which will result in an unequal ITD and IID because the signal will arrive at the left ear later than at the right, with a lower intensity [ibid.].

In figure 7.5 we can see the interaural time difference of the soundwave reaching the right ear due its distance from the sound source. The interaural intensity difference is affected by 'head-shadowing', in which the head acts as an obstacle for frequencies above 2000Hz (below 2000Hz the "wavelength can diffract around the obstructing surface") [ibid.]. Localisation is consequently affected by environmental ambience produced by the room's architectural characteristics [Kendall et al, 2011, p3].

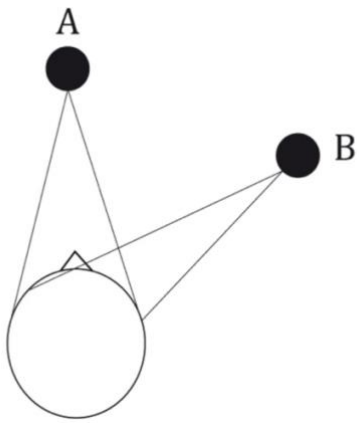


Figure 7.4 – localisation examples
[Roginska et al, 2017, ch1]

Musical parameters such as "pitch, rhythm and timbre can be perceived with relatively high degree of accuracy" [Bates, 2009, p13]. As with most things, personal experience can affect how successfully each individual perceives these parameters. This is also true with regard to sound source localisation accuracy, which is a "deeply embedded cognitive capacity" [Kendall et al, 2011, p1]. But there are several issues that can produce a 'localisation blur' [Roginska et al, 2017, ch1]. Early arriving reflections for example, determined by the size and shape of the room can reduce localisation accuracy [Bates, 2009, p21]. Kendall et al explain why certain

issues occur in spatial audio, highlighting how spatial ideas do not always translate in real-time due to nuances in spatial hearing and thinking [2011, p1].

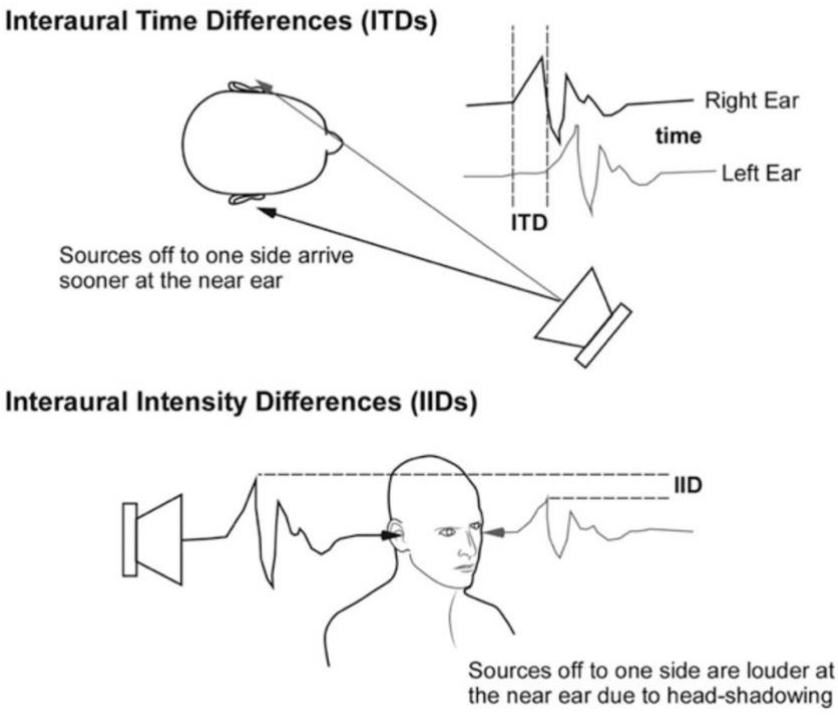


Figure 7.5 – ITD and IID examples
[Roginska et al, 2017, ch1]

One such common issue is 'precedence', which is an auditory mechanism that allows us to determine the direction of sound in complex sonic environments. When a sound is heard directly from a source, in addition to indirect sources including distant loudspeakers and reverberation, precedence will be given to the first-arriving direct sound [Kendall, 2010, p234], whilst other later-arriving sounds are suppressed [Kendall et al, 2011, p2]. Precedence therefore effects spatial panning, as some listeners are likely to be closer to one speaker than another, which will vary depending on loudspeaker distance [ibid.]. Only in the sweet-spot in which all speakers are equidistant, precedence will not take effect [ibid.].

Precedence is determined by 'arrival time difference' (ATD), and as such each listening position will have varying degrees for ATD [ibid.]. Between 0 to 1ms a phantom image will be created closer to the location of the leading loudspeaker; from 1 to 5ms the perceived location of the sound is place in the leading loudspeaker whilst all other sources will be

suppressed [Kendall, 2010, p234]. At 5ms a threshold is reached in which precedence is released, and sound events from distant loudspeakers are heard as echoes [ibid.]. It is unsurprising therefore that the sweet-spot is larger in smaller performance spaces [Kendall et al, 2011, p2], and explains why spatialisation techniques are less effective when the performance space is scaled up [Kendall, 2010, p234].

Localisation that takes place in the front left-right axis is the least prone to error – "people seldom misjudge whether a sound is on the left or right" [Kendall, 2010, p230]. However, in spatialisation techniques such as circular panning, its effect is reduced because the phantom image produced by speakers to the side of the head is not as coherent as in-front, even in the sweet-spot - something Kendall et al [2011, p2] describe as *image dispersion*. This phenomenon also effects front-back spatialisation, especially when there is no head rotation [Kendall, 2010, p231].

Recordings that have encoded HRTFs produce a *crossover* effect when performed through loudspeakers, requiring crossover cancellation to resolve the issue [ibid, p3]. Equally, localisation due to elevation without head-motion is not as accurate as in the front horizontal axis, and can produce inaccurate impressions that are directly influenced by the sounding objects frequency [Kendall, 2010, p237]. "Very low-frequency narrow-band signals localise below the floor and only very high narrow-band signals localise at the ceiling" [ibid.].

Localisation is a key feature of Spatial Music. *Spatialisation* (also 'audio spatialization', 'audio rendering', or 'sound imaging') is the process of implementing sound trajectories as localisation cues in which the listener is encouraged to localise sounds in a 3D audio environment [Wozlniewski et all, 2006, p144]. Harley [1999, p148] explains that spatialisation techniques such as "spatial projection, sound location and direction" can become important structural elements in the music. Localisation is easier for a listener when the sound is moving than when stationary [Malham et al, 1995, p66], such as creating sound trajectories that move front to back to enhance spatial qualities [Austin, 2000, p13]. This is also the case with sounds that have sharp attack characteristics and those with wide band signals (high frequency content) [Malham, 1995, p66]. Inversely, sounds with no transient attacks are harder to localise [Kendall, 2010, p237]. However, sounds with continuous sharp attacks are

dramatically affected by room reflections and therefore decrease location accuracy [Kendall, 2010, p236].

Moylan [2012] discusses how spatial characteristics can add important sonic qualities to music, such as create spatial clarity between instruments and voices, and balance music meaning to develop emotional communication. Harley [1999, p150] provides his own ideas regarding spatial separation and its importance:

- "Spatial separation clarifies the texture - this is particularly important if the music consists of several different layers located in the same pitch register.
- Spatial separation is equivalent to the separation of textures in pitch space. One can hear separately layers of music that are located in different registers, and layers that originate from distant points in performance space.
- Spatial separation permits a greater complexity in the music, which may therefore, include more unrelated elements perceived simultaneously.
- Spatial separation makes exact rhythmic coordination impossible - distant groups should avoid simultaneous, identical rhythmic patterns.
- There are no optimum positions of the listeners or the performers in the hall, each situation is different."

The overall spatial image can be controlled with accuracy when HDLA systems with identical speakers have been distributed equidistantly from each other [Wozlniewski et all, 2006, p145]. The control of the image and 3D soundfield is an integral element of spatial music and applied in sound diffusion practice.

> "*one should be able to expand these dimensions: … exaggerate closeness, exaggerate distance, play with the height of the image, thereby adapting the space composed into the music to the dimensions of the listening space.*" [Austin, 2000, p12]

Such exaggerations can even shift the entire soundfield, "creating the impression that the listener is moving in space" [Harries, 2011, p99], a practice that can be effectively achieved using Ambisonics.

The use of the human localisation mechanism as a musical technique is incredibly attractive, and can be implemented using the movement of sound sources (spatialisation) either through

loudspeakers, or the actual physical presence of musicians. This can be achieved with great success to produce as Bates emphasises, a "physicality and dynamism" to a performance [Bates, 2009, p.4]. This is a technique that has been consistently used from early antiphonal music to the birth of the electroacoustic medium due to its foundation in spatial hearing. Spatialisation continues to be relevant owing to new technologies becoming available, enabling the emergence of unique approaches to this performance paradigm across the arts. These provide endless creative possibilities to tailor a work to a specific performance environment [Truax, 2012, p9] by using the space artistically to add expressiveness to the musical performance [Bates, 2009, p.216]. Thus, localisation as a sound processing parameter, such as the position of sound-sources through innovative approaches, and the addition of spatialisation techniques, will play an important role in the investigative intentions of this study. The key aim is to discover whether localisation, with specific regard to sonic clarity, as well as the movement of sound sources as a means of spatialisation (physical or virtual) can enhance immersivity in music performance.

7.4 - Visual Processing

Music making is a uniquely human endeavour.

> *"music-making behaviour covered important evolutionary functions such as communication, cooperation, social cohesion and group coordination. Only humans learn to play musical instruments, and only humans play instruments cooperatively together in groups... demanding task for the human brain that engages virtually all cognitive processes that we know about, including perception, action, cognition, social cognition, emotion, learning and memory"* [Koelsch et al, 2005, p578]

The physical movement of body and limbs are known as 'gesture' and embody expression [Smalley, 1996, p84], which as Camci [2012, p2] explains - act "as a compositional tool for the artist and a cognitive component for the listener". Dennis Smalley explains 'utterance' as a voice generated by a human body, one that acts as a "vehicle of personal expression and communication", announcing the presence of a human even when used in electronic music [Smalley, 1996, p86]. Both gesture and utterance, as well as human agency and surrogacy (which we will explore shortly), will be assigned under the category of 'physical action' for this

study, as they all employ some level of bodily movement. Historically we have been accustomed to listen to music that offer both gesture and utterance as audio-visual expressions, therefore, both are strongly embedded within us culturally [Smalley, 1997, p112]. Smalley adds that our experience of listening to instruments is related to years of unconscious audio-visual conditioning, and therefore our understanding of musical sounds and meaning is strongly embedded in these experiences [Ibid].

> *"… gesture is rooted on archaic principles dating from the very first steps in communication between human beings. It is rooted on the first traces of languages. It is not just a physical gesture. Is a communicative gesture. It is a code. Has a meaning. It is not just understood and translated by the instrument; it is also understood by the audience who is carefully watching the performer make a succession of gestures conforming a dialogue. A musical discourse with its own choreography."* [Perepelycia, 2006, p58]

If for example we have experienced the performance of a violin, guitar, drums or any other instrument for that matter (in real world circumstances), we recognise the sound has been made by human gesture, even if we no longer have the visual aid. Depending on experience (there will be a difference between the casual music consumer and the experienced music practitioner), we can use our imagination to identify the physical actions that occurred to propagate that sound [Smalley, 2007, p39]. We can easily discern the difference between the plucking of a guitar, the striking of a drum and the blowing of a trombone. We can even distinguish the difference between two saxophones, simply based on tone (as we do day-to-day with timbres of different human voices). Furthermore, MacDonald [1995, p89] explains that we instinctively assign gestural actions to sounds that we may not even recognise, simply due to this innate conditioning. This is a useful tool in nature, in which we can assign visual cues to non-visible sound objects. Smalley [1997, p110] calls our instinctive "attempts to relate the sounds that we hear to things that exist in the real world" as 'source bonding'.

> *"the natural tendency to relate sounds to supposed sources and causes, and to relate sounds to each other because they appear to have shared or associated origins."* [Smalley, 1994, p9]

When a listener hears sounds in space, what the listener perceives and understands can be most accurately described as events that take place in space. These are events that typically involve objects, actions and agents. Over the course of human maturation, each person

gradually learns to understand more complex and more nuanced relationships among these three. Auditory spatial imagery and spatial meanings can arise when listening, when remembering or when imagining. This tells us that the listener's spatial capabilities are not simply a product of immediate perception [Kendall, 2010, p228]. Hence, it is not surprising that when listeners have sensory experiences of sound alone, they are able to make sense of these experiences as events that take place with objects, actions and agents, even though these constituent elements may be unobserved, obscure or unknowable [ibid, p229]. Kendall observes that this is how the mind "sustains spatial thinking" [ibid, p231].

Gesture in the traditional sense of music performance (let's take for example a live performance by a famous pop/rock artist) are incredibly important in how they convey emotional intention. Whether in an energetic upbeat song or a ballad, physical actions help the audience better understand the emotional intention, and therefore generate engagement [Smalley, 2007, p42]. Live performances continue to be extremely popular, possibly for these precise reasons, where human physical actions deliver a visual expression that create an emotional connection for the audience which cannot be replicated by hi-fi systems, headphones or even television, as it excludes the energy conveyed by the physical presence of the musicians and the audience. The *liveliness* of a situation when determined by human physical presence has great influence on audience perception, and encourages the listener "to acknowledge the physical space" [Harries, 2011, p88]. The kinaesthetic audio-visual image can be just as powerful on video capture as it is in real-time [Perepelycia, 2006, p58]. Consequently, Film and TV may be just as successful at conveying meaning as in a live performance, but the experience still defers. Smalley [2007, p42] calls this '*mediatised*' performance, in which the performance and gestural space is transmitted by technology.

It was not until the advent of electroacoustic music performance (one which relies on loudspeakers) that neither the physical representation of vocal utterance nor instrumental gesture were essential [Smalley, 1997, p111]. In electronic music, sounds can be produced without the presence of instrumental or vocal performers, and therefore, do not embody the physical actions with which we have so far been familiar with [Iazzetta, 2000, p266]. It can therefore be expected that the listening experience between live music that includes performers and that of electroacoustic music that does not, will be perceived very differently

by audiences. Leppert [1993] explains that music is abstract, intangible, and ethereal, therefore the visual aspects are necessary for both the audience and the performer to establish and communicate its location and cultural significance within a society. Although trends are certainly changing, historically we have been conditioned to expect music with a certain level of physical action to place meaning against aural events.

> *"If you take away or weaken the tangibility of the known, visual, gestural model and the direct, universal articulations in utterance, then you undermine the stability of the conscious and unconscious reflexive relationship that the listener seeks."* [Smalley, 1996, p96]

Usually, gesture is produced by a performer that acts upon mechanical "sounding bodies by fingering, plucking, hitting, scraping and blowing [Smalley, 1996, p84]. This performer can be described as a '*human agent*' to that gesture, otherwise known as '*agency*' within the acousmatic medium [Stansbie, 2013, p43]. Barrett prefers the term '*human physical action*' rather than human agency as it may be perceived as too specialised [Barret et al, 2018, p408]. This thesis has adopted the term 'physical action' for gesture, utterance and human agency, as the presence of human activity in live performance is implied. In the field of electroacoustic music, the human agent is able to create similar acts of gesture that are commonly related to performance by the "manipulation and processing of sound" [Ibid., p28]. Stansbie [2010, p20] goes on to explain that the quality of the musical performance delivered by the agent in acousmatic music still results in the "communication between the listener and the performer". Similar to the traditional format of live music that includes musicians by "dramatizing and exaggerating" the sound delivered by the fixed loudspeakers [Stansbie, 2013, p49].

> *"Pressing a key or sliding a bow during a performance are movements that hold a meaning in themselves: they establish how a sound will be produced, they determine some characteristics of that sound, they set up connections with previous sonic events, and, at the same time, they furnish an articulatory path to further sounds. Obviously, they are more than simple movements, they are meaningful gestures"* [Iazzetta, 2000, p261]

We can explain gesture as any type of physical action, such as hand gestures, bodily movement that touch, grasp and manipulate physical objects to form sounds, whether conscious or unconscious that convey musical meaning [Perepelycia, 2006, p55]. We may

attribute this definition to the physical actions used by electronic musicians, especially those that use MIDI controllers, synthesisers and computers as instruments central to the performance. Iazzetta [2000, p260] explains that gesture in electronic music performance is not just the movement of faders and knobs, but they are any movements that express something, or as Camci [2012, p2] labels "as something significant".

The significance of physical action becomes particularly pertinent when we assign it to any type of electroacoustic music, especially in acousmatic music in which sound sources and their causes have been removed and detached from the original sounds [Smalley, 1997, p112]. This means that the audience no longer has visual cues to attach meaning to the sound they hear. This becomes even more difficult when the sounding sources heard are ambiguous to the point in which the listener cannot 'source-bond' to sound previously experienced. Where sounds exist that may or may not be easily identifiable, especially when there is neither the presence of gesture, utterance or agency, Smalley [1996, p85] uses the term '*surrogacy*' to define their existence, and categorises them as:

- *First Order Surrogacy* – where musical sources are easily recognised
- *Second Order Surrogacy* – traditional instrumental gesture, which includes recordings of identifiable musical instruments
- *Third Order Surrogacy* – where gesture is inferred or imagined in the music, with a degree of ambiguity that makes the listener unsure about the reality of either the source and/or cause or the sound
- *Remote Surrogacy* – concerned with gestural vestiges. Source and cause become unknown and unknowable as any human action behind the sound disappears

[Hewitt, 2006, p8]

When the agent increases the levels of surrogacy from first order towards second and then to remote, the sounds increasingly become removed from their original qualities to become unidentifiable - Smalley describes this process as 'gestural surrogacy' [Smalley 1997, p.112].

> *"In one category we find sounds snatched, borrowed, captured by microphone from nature or from culture, second category are those sounds specially created for musical use: instrumental and sung sounds, in a third category are those electroacoustic sounds, synthesized and removed from any familiarity. Therefore, at one extreme of the sound-field are sounds whose source can be*

identified, but at the other are sounds whose source the listener may well not be able to deduce." [Smalley, 1996, p77]

It has been established that in some fields of electroacoustic music, an issue may arise due to the absence or reduction of physical action, which means that there are likely to be "intrinsic cognitive differences" in both the audience and performer experiences [Camci, 2012, p1]. The development of technology, such as the power of laptops, the quality of software synthesisers and sample packs, as well as the diverse functionality offered by modern MIDI controllers, mean that there is almost no limitation to what a live electronic music performer is able to create. As Smalley expresses, it is "a bewildering sonic array ranging from the real to the surreal and beyond" [1997, p107], whilst asserting that the electroacoustic medium has revolutionised music [Smalley, 1996, p77].

The rise of DJs as festival headliners maybe proof of this established musical form. It is also worth considering that electroacoustic music is not confined by the instrument or voice [Ibid., p96], or its technical ability, whilst production techniques that were once confined to the studio, can now be recreated in real-time. Smalley therefore believes that this performance medium should be celebrated, not as "a mere extension of vocal and instrumental resources", but "for its originality and imaginative revelations of human experience' [Ibid., p77].

It still remains that electronic music performances (those that normally employ a single laptop performer) present a dislocation between what is seen and what is heard [Emmerson, 2007, p110]. Emmerson explains that in laptop music, tiny physical gestures by the performer can create quite exaggerated sonic changes [Ibid., p93]. He goes on to discuss that this is often seen as a problem in this form of live electronic music, where the audience is usually unable to make a connection between the performer's physical actions and the resulting sounds [Ibid., p105]. The use of MIDI controllers coupled with cameras, where the performers actions are projected to large screens, can help to mitigate this disconnection. It remains true however, that these physical actions are minute in comparison to the change in musical sound, such as dynamics, texture etc. A laptop performer for example, can affect the dynamic range of a piece with a single small gesture, whilst in an ensemble, it requires all of the

musicians to adopt this dynamic transformation through their physical actions, which may be very visual.

Menzies [1999, p37] gives an example of how a simple melody such as 'three blind mice' performed by MIDI data (even with the most elaborate programming in place, which considers various expression technique), cannot compare to the human expression delivered by a violinist, which includes not only gesture, but facial expression. Therefore, the challenge for electronic musicians is how to mirror what is heard with physical actions, especially when more spectacular sounds would necessitate more spectacular gesture (which tend to be quite theatrical) to be proportionally relevant [Caesar, 1992, p24].

When a performer is present in electroacoustic music, physical action is therefore a critical factor in the perception of the music [Menzie, 1999, p37]. Electronic music must attempt to attach physical meaning to the sounds heard, where adequate representation of the musical material through gesture would enrich the overall experience and better translate the musical narrative [Perepelycia, 2006, p8]. The electronic performer therefore must make a fully concerted effort to assign meaning to the music in as much detail as possible. This means, that not only do physical actions need to be visible, but so should the electronic equipment used to create and propagate the sounds, such as MIDI controllers, samplers, synths, decks etc. The purpose here being to allow the audience to construct as much meaning from those devices as is attached to traditional instruments. The performance aspect should represent some level of emotional interpretation as would be excepted by more traditional forms of artistic expression. As Perepelycia demands, performers should certainly not spend time remembering which actions, such as which buttons, knobs and faders are assigned to which parameters [ibid.].

Although electronic music seems to have gestural limitations, theoretically, computer music has fewer limitation in what can be conceived compositionally and conceptually, where performances can be enhanced by implementing various technologies [Perepelycia, 2006, p42]. Both Ableton Live and NI Maschine include a '*Link'* function that allow tempo-synching across a network to various audio-visual devices and software applications. This means that performance aspects can be limitless, bound only conceptually and by the artists access to

appropriate technologies. The application of such performance systems within this field is still in its relevant infancy, certainly from a compositional and performance perspective.

Barry Truax [2000, p123] states his opinion that the limitations in this field of performance are linked to the listeners personal experience with the format. The varying levels of experience permits individuals to relate to the material differently, or in some cases not at all when relevant experience is absent all together. We may compare a seasoned opera lover as an example, who will perceive a purely electronic performance very differently to a young producer who has grown up on computer generated music. Electroacoustic music performance therefore, could also be considered to be its infancy in that respect, meaning that as listeners we are likely to build familiarity with the electroacoustic format over time, as we have with a choir in a cathedral, or a band in a venue [Wright, 2010, p6]. This demonstrates that the perception of physical action is deeply embedded by cultural experiences, and as the spread of electronic music performance increases, it may be the case that audiences might eventually just as easily assign musical meaning to the triggering of a pad, as they might to the plucking of a string.

Multichannel formats such as those discussed in chapter 3, can create full three-dimensional audio “environments and soundscapes of great immersive impact for the audience” [Truax, 2000, p122]. Multi-disciplinary performances that include live musicians, visual effects and choreography are common practices, and well established for major musical artists. Consequently, audiences have high expectations from live performances, a prospect that must be considered when presenting electronic music with limited human physical action. Electronic music performance must provide something different than what is presented on record and what can be experienced at home, because audiences expect a rewarding experience in exchange for the price of their ticket [Austin, 2000, p11]. The composer of live works in this field must make decisions based on the audience perspective [Austin, 2001, p22]. Stansbie [2013, p36] summarises the words of Godlovitch, that performances which reach out to audiences should “specifically and directly (be) intended, designed, or meant for audiences”.

Electronic music that employs loudspeaker orchestras and the spatial techniques used in various electroacoustic practices, have yet to become commercial products. This is possibly due to the expensive technical resources required, but the hope is that as the technology becomes cheaper, more venues will be able to deploy large loudspeaker arrays. When audience exposure to spatial music increases, owing to more music being delivered in these formats, it is likely listener enjoyment will also increase [Barrett, 2016, p36]. The modern electroacoustic composer that wants to implement spatialisation in their music with success, must find a balance between providing the audience with unique sonic experiences whilst ensuring the music remains broadly palatable.

Composition that is intended for live electronic performance must make decisions which consider the concert and the possible performance contexts one seeks to convey [Austin, 2000, p12]. Smalley [1997, p108] argues that composers conceive musical material such as the arrangement subjectively, which will undoubtably be perceived by listeners differently. This is a discourse between what the musical composition is attempting to convey and what the audience will ultimately perceive, and which establishes the subjective nature of music to the individual.

> *"Abstract concepts like melody, harmony and tonality have been established and widely acknowledged over the course of centuries. These fabricated structures have formed a musical language that is now engraved to our deep-seated mechanisms of music perception*." [Camci, 2012, p2]

Nonetheless, composition and performance aspects are entirely interlinked, and this is far more pertinent in the field of spatial music, in which one seeks to exaggerate the movement of sound within a given space. As Harries highlights, it is quite possible for movement to occur by all three different entities, the performer, the loudspeakers and the audience [2011, p95]. The possibilities to some degree are endless - a matter of resource and will. It is argued that what technology potentially offers to the performer as opportunities, far exceeds the output of what composers have produced thus far [Barrett, 2010, p1]. This is perhaps due to the fact that for most composers, the opportunity to write material within a large loudspeaker array, which allows for exploration and experimentation, is highly unlikely. It is possible that in due course, more composers will be able to create spatial music in ideal environments.

It is evident from this discussion, that physical action in any performative form, plays an integral role in the perception of a musical work. This element in which listeners codify music for their own enjoyment is of biological and cultural significance. Its importance was emphasised by participant responses, post project one (chapter 9), prompting further investigation of this parameter. This has been accomplished through secondary research discussed in this chapter, and through primary research in projects 2 and 3. This process has revealed that in the case of immersive music performance, the presence and clarity of physical action is essential.

7.5 - Audience Engagement

The performing and creative arts have always relied on the consumer to survive. Whether through the medium of live performance or mediated forms (such as CDs, Vinyl, TV, Film etc.), the audience has been central to the success of a single or collection of works. Yet, as Zhang et al [2016, p1] point out using Kattwinkel's assertion, that there is a tendency from the arts to relegate audiences as simple receiving participants. In fact, arts organisations and artists should consider an audience centred approach if they wish to develop a sustainable business, because the audience is their customer [Beeching, 2016, p395]. Beeching's [2016, p396] research is focused on classical music, but her comments are relevant across the arts when she highlights the need for musicians "to understand how their performance is perceived, …what the audience responds to and why". She adds that musicians must question the value of the performance from the audience perspective, where a healthy level of reflection can lead to a broader consumer reach and a better product [Beeching, 2016, p395/396]. Kolb [2000, p13] describes the classical performance approach as fairly contrasting to that of popular music, in which audiences "expect to be entertained and to enjoy all aspects of the concert, not just the music" [Kolb, 2000, p25].

> *"The popular music concerts which most young people have experienced are dramatically different. All aspects of the performance are designed to appeal to the emotions, from the lighting to how the performers are dressed. The audience is not expected to silently observe the performers. In fact, the audience and its reaction to the music is an indispensable part of the concert experience."*
> [Kolb, 2000, p13]

Studies in the field of *Audience Engagement* with regard to music performance are limited and even further underrepresented in live electronic music performance [Lai et al, 2013, p170]. However, there are many studies of audience engagement across the arts that are relevant to this research. Firstly, we should clarify that the principle of 'audience engagement' in the performing arts is highly subjective, where audience expectations, wants and needs will vary considerably, making the term 'audience engagement' difficult to define. Shirzadian et al [2017, p4] uses Attfield's definition of engagement as "a quality of the user experience that emphasizes the positive aspects of interaction, in particular the fact of being captivated".

The work of Radbourne et al [2018], collated debates from various studies undertaken in the field of audience engagement, for their paper '*The audience experience: Measuring quality in the performing* arts', which will be central to this discussion. In this paper, the authors highlight the following key characteristics as audience engagement: the ability to arouse emotions, stimulate physical reactions, tap into memories and fantasies, and trigger a cognitive response [Radbourne et al, 2009, p18]. It is unsurprising that triggering an emotional response is a key component of the performing arts as a form of entertainment. A participant in a study carried out by Shirzadian et al was quoted as saying:

> *"Emotions are always unique - what you feel in this moment, you will never feel in this way again. This is why people go to concerts - to feel this uniqueness of the moment'* [2017, p15]

Another appropriate definition provided by Shirzadian et al [2017, p5] (taken from research undertaken by Jenett et al.) is the ability for entertainment to immerse the consumer in a manner in which they 1) lose awareness of time, 2) lose awareness of the real world, and 3) lose their sense of being in a task environment. Although the study focused on games, it is pertinent to use this description when defining the level of audience engagement from a single user event. Rumsey echoes this argument that:

> *"Immersion is a phenomenon experienced by an individual when they are in a state of deep mental involvement in which their cognitive processes … cause a shift in their attentional state such that one may experience disassociation from the awareness of the physical world."* [Rumsey, 2020, p390]

The general public spends a lot of their disposable income on the arts, and therefore it is predictable that as consumers they wish to shape their own experiences [Radbourne et al, 2009, p17]. It is the creative industries' responsibility to create marketing strategies that deliver events which meet their consumers needs and empower audiences [ibid, p18]. Beeching suggests that organisations use an approach in which they "uncover their consumers' needs and wants" before creating methods to meet them [2016, p398]. This may seem fairly obvious and common practice in the corporate realm (such as major record labels and publishers), however, with the music DIY route becoming common place, it is an approach that all artists should consider when developing a musical product. The importance of this becomes apparent when audience needs have been sufficiently met to the extent that they re-attend, or even better, become life-long fans and supporters of a particular artist or organisation [Radbourne et al, 2009, p19]. Audiences of this kind will consequently provide artists with the financial stability and career sustainability they desire.

Radbourne et al. [2009, p18] highlight that the decisions made on how public funding was spent in the arts (in Australia), was heavily influenced by artists, because the artists themselves were chosen to make such decisions. Yet, as we shall explore, professionals perceive art differently to that of the general consumer, and so decisions were skewed in the artists favour rather than the audience. Radbourne et al [2009, p27] provide us with a highly useful list called the 'Arts Audience Experience Index' when developing and measuring audience engagement:

1. Knowledge
2. Risk
3. Authenticity
4. Collective Engagement

Knowledge

The aspect of knowledge acknowledges the importance of information, which enables audiences to better understand and achieve a greater perspective of the performance they are experiencing. Examples of knowledge include performance programs, visuals, and direct engagement with the audience by performers or the director/conductor, in which

information is expounded [ibid, p19]. The function of learning through performance can also be considered a characteristic of audience engagement, as it requires audiences to take active participation in the information presented [ibid, p23].

A study by Kolb [2000] presents to a group of participants with no prior experience of classical concerts, a series of performances with the aim to investigate the level of engagement through qualitative questionnaires. His findings demonstrate the importance of knowledge on several levels, where the participants -

> *"described the audience as people who "have studied and appreciate music," or as "intellectuals with cultural backgrounds." The students all believed the audience had access to some special knowledge that allowed them to find classical music enjoyable. They could not feel at ease at a classical concert because they would not have the education necessary to understand and appreciate the music"* [Kolb, 2000, p17]

The lack of prior knowledge of classical music, such as performance and compositional characteristics, made it difficult to consume the performance in a manner to which they are accustomed to, which in turn made them feel that they did not belong [ibid, p19]. This absence of knowledge theory can also be attributed to other musical styles, such as Jazz and certain types of electronic music in which audiences are in the dark about compositional and performance practices. Inclusivity is therefore an important interaction characteristic, in which event-goers can enjoy the performance without "requiring specific musical skills" [Zhang et al, 2016, p4]. This lack of relatability to the material was further highlighted when the participants finally recognised some of the music from its synchronisation in movies, enhancing their overall enjoyment [Kolb, 2000, p19]. This characteristic of relatability cannot be ignored, it is why audiences generally attend performances of the artists they already enjoy, because they know the music and have some understanding of who the performers are, including in some cases, their personality, their cultural background and ideology.

We can point to various popular artists who have had significant success in engaging with their audience on a personal level through live performances and their online presence. It is surprising that many studies in the field of spatial and immersive music, whilst investigating audience engagement, employ work that does not meet these characteristics, where abstract

and improvisational music seems to be common practice. A study by Lai et al [2013, p173] which investigated the audience experience of a music performance noted this exact sentiment, that the music was "too improvisational", and that by creating a "predefined structure", it would better meet audience expectations, and therefore enhance engagement. The experiments by Shirzadian et al. [2017, p18] demonstrated that participants "feel more immersed in the event … when they like the music". This supports the assertions made by several studies mentioned thus far, that the audience should be central to the creative and delivery process, not secondary, and certainly not treated as receivers but instead as contributors.

Program notes can provide an audience with a better understanding of the performance structure, the musicians, the conductor/director and the narrative. Kolb's [2000, p24] study indicated that this information should be available to all as a standard, and not to be obliged to be purchase as an add-on. In addition to this, participants found the lack of communication with the audience either verbal or non-verbal "confusing" [Ibid, p22]. It can be argued that some forms of music are intrenched in tradition, which younger audiences are neither aware of nor sufficiently familiar with. In contrast, the 'pops' concert which employs some of the (popular music) performance characteristics they would expect, such as a visually engaging stage, including vivid clothing and lighting, was enjoyed much more by the participants [ibid, p21]. This demonstrates the importance of meeting audience expectations, whether that is a multi-disciplinary popular concert, or a traditional delivery of classical music.

Several studies and experiments have identified that the addition of visual elements can enhance the audience enjoyment of a music event, including visuals, lighting, and even smell (synaesthetic) [Shirzadian et al. 2017, p3].

> *"The results indicate that the visual layer could add value to the concert experience, providing a higher level of immersion and feeling of togetherness among people"* [ibid, p2]

Visuals should be designed with the audience in mind, not necessarily the musicians who may find the visuals distracting [ibid, p7]. However, visuals should not only consider the choreographed variety, but also the architecture and arrangement of the performance space

[Lai et al, 2013, p172]. Event organisers and composers should consequently consider what is an appropriate performance space for a given event, and how the space can be arranged to enhance the overall experience.

Moreover, there is a connection between a performer's physical actions (gesture), and audience engagement, which is firmly linked to the idea of 'knowledge'. Let's take for example an electronic music performance using laptop devices and MIDI controllers, delivering a set of music to an audience that has no familiarity with neither the sounds projected or how the devices are used in performance. Lai et al [2013, p173] speak specifically to this problem of "action-to-sound", where actions need to be observed clearly for them to be understood. These ideas further corroborate the importance of visual processing examined in the previous chapter.

> *"live performance … often becomes challenging because interaction technology allows arbitrarily mapping of bodily movements as controls to produce sound. This is especially a concern if a performing artist attempts to engage and build a connection with her audience"* [ibid, p170]

Risk

The aspect of 'Risk' relates to potential loss or gain from the audience perspective. Types of risk may include [Radbourne et al, 2009, p20]:

- *Expectational risk* – will this event meet my expectations?
- *Economic risk* – is this event worth the cost?
    - It is a matter of satisfaction versus potential expense and can relate to possible socio-economic factors. We may consider the expense of an Opera as a contributing factor for the type of demographic that attends such concerts.
- *Psychological risk* – is this going to challenge me in a way I find uncomfortable?
    - We may consider the need to have some prior knowledge to fully enjoy the experience. It may also be that the performance does not reflect the individuals' ideologically beliefs, or will they feel uncomfortable due to some level of participation or closeness to strangers. However, research has demonstrated that even when individuals felt initial discomfort due to proximity, that exact same reason consequently strengthened the overall experience [Radbourne et al, 2009, p23]
- *Social risk* – is there a social risk of how I want to be perceived by attending this event?

As explained previously, audiences are a consumer of the arts, and so their spending will reflect their personal preferences. It is not unusual therefore, that they do not want to be entertained in a manner that is perceived as risky for some or all of the reasons highlighted above. Nevertheless, these risks do not have to be framed as negative, but also as positive opportunities to experience something new and exciting, which is certainly relevant in the experimental arts, as well as academic research in the form of this study.

> *"The onus is on arts organisations to maximise the perception of positive risk and minimise that of negative risk"* [Ibid, p20]

Authenticity

> *"The greater the authenticity perceived by an audience member within a performance, the greater her or his enjoyment of the experience*" [Ibid.]

We could use several pop music artists as examples in which the authenticity of the material is highly valued by the audience, whose songwriting and delivery approach can be deemed as an authentic reflection of their lives and emotional state - something that the consumer can connect to on a personal and emotional level. We could also use examples of jazz or opera in which fans wish to be enthralled by an authentic experience that fulfils their expectations, whether that is a virtuosic instrumental technique reflective of the style, or staying true to the composers' original intentions. Both of these latter points can be considered types of authenticity [Ibid, p20].

- Does the type of performance offered contain a certain level of technical standard that is synonymous with that musical genre?
- Does the performance meet the audience's subjective perception of authenticity, as something real and believable?

This subjectivity notion is so pertinent that some audience members can have a totally different 'authentic' experience than others from the same performance, which is linked to the knowledge category. Someone who is a professional artist, whether a musician, actor or sculptor, is likely to have the knowledge to better understand the concepts employed in Jazz, a nuanced film narrative, or the technical aspects of sculpture making respectively. This does

not have to be a professional versus amateur consumer model, but any field in which there are levels of experience and knowledge that directly impact audience engagement.

Radbourne et al [ibid, p21] highlight Wang's theory that authenticity can be experienced individually and collectively (this concept may serve to explain trends), whilst authenticity and general engagement reflects the audience's ability to construct some meaning from what is being performed, including that of physical action with regard to gesture and utterance [Ibid, p21].

Collective engagement

This category refers to an audience being engaged by the performers and other audience members. Three types of engagement are outlined as [Ibid, p25]:

1. "Communication between performers and the audience
2. Communication from the audience to the performers
3. Interaction between audience members"

This does not mean it has to be explicitly verbal, it can be experienced directly or indirectly. The key objective to create a sense of collective belonging [Ibid, p21], whilst delivering a performance that can be considered authentic and of a desired quality [Ibid, p26].

In music, a non-verbal engagement may exist as an emotional vocal performance, a virtuosic and technically impressive delivery, or an energetic and powerful performance with movement. As before, we can relate these to the physical actions of performers, including gesture and utterance.

Collective engagement can also be considered to be the direct engagement of a performer with an audience. We may wish to picture Freddy Mercury addressing a full capacity Wembley stadium during Live Aid in 1985, in which a call and response segment delivers a rapturous response from the audience. That audience has experienced something powerful as a collective, which is further enhanced due to the uniqueness of that single shared moment. Furthermore, that experience can transmit beyond the live environment, but also to every

individual around the world watching it live on a television. This is a simple example of the power a single performer can have to entertain an audience. Shirzadian et al [2017, p4] discuss the work of Hall et al from '*The Silent Language'*, highlighting that as humans are social beings, our opinions and affected state are greatly influenced by others around us, whether spatially (live) or virtually (TV, Radio, VR). This equates to the feeling of 'togetherness' - a communal feeling experienced as part of a group [Ibid, p6].

'*Liveliness'* is the term used to refer to a performance witnessed in real-time, which is shared between the audience and performers, as well as between audience members and enhances the collective experience [Ibid, p16]. Using the idea of liveliness, we must also acknowledge the effect of the performance space, in which the audience experience is stimulated by the physical space and its constituent parts, such as its overall architecture, stage presentation, seating arrangement, speaker systems etc [Radbourne et al, 2009, p26]. All of these factors produce a unique spatial relationship that can only be experienced in that moment of time. The previously discussed recording practices of Snarky Puppy are just one such example. Other acts, including Bjork and The XX, have adopted immersive techniques to create unique and interactive experiences. This is something audiences are continuously seeking out [Ibid, p24].

Unlike music where direct engagement between audience and performers is natural and effective, theatre has looked to engage with audiences in a manner that does not require direct communication, but instead pursuing a level of immersion that utilises spaces as part of the narrative. Plays have employed multiple narratives that utilise an evolving performance space with audiences as participants. *Punch Drunk* for example, is an established immersive theatre company that is highly revered for its emphasis on placing its audience at the centre of the action [punchdrunk.com, 2021].

Developments in immersive theatre have greatly influenced this study, not specifically the idea of space as narrative, but instead the inclusion of the audience as an important factor during the development and delivery of a performance project. Harries suggests [2009, p2] that a creator may develop a performance specifically designed to produce an environment that is as engaging as possible, in some cases, a 'co-authorship' approach may be employed

in which the audience is part of the creative process. There is also the option of “open” works, where audiences are invited to co-create with the author [Ibid, p3]. Harries investigated audience engagement using different performance scenarios, in which the participatory installation proved to be the most successful [ibid.]. That is not to say that direct participation is a key factor to enhance collective engagement, but instead, this chapter has underlined the nuanced techniques that can be employed to bring audiences together and create unique experiences.

DMI’s are Digital Music Interfaces, which enable Human Computer Interactions (HCI), and are useful tools for producing and processing audience participation [Zhang et al, 2016, p2]. These can be examples such as software or hardware devices that enable audiences to directly participate in the performance event. TouchOSC used in Project 3 of this study is just one such example, with Open Symphony Web Client another [Zhang et al, 2016, p4]. Figure 7.6 below shows the interface (GUI) of the application used to “investigate the relationships between audience and performers in a creative context”, in which performers had to directly respond to the decisions of the audience.

The use of HDMs (head-mounted displays) in research studies have also been demonstrated to improve the user experience and develop a more immersive environment [Kraj et al, 2020, p2]. The work of Kraj et al, in which participants responded to a performance with and without HDMs, demonstrated that the technology improved the user’s level of immersion, commenting on the spatial features of the performance space, and influenced their physical actions (wanting to dance), which did not occur when HDMs were not used [ibid, p9].

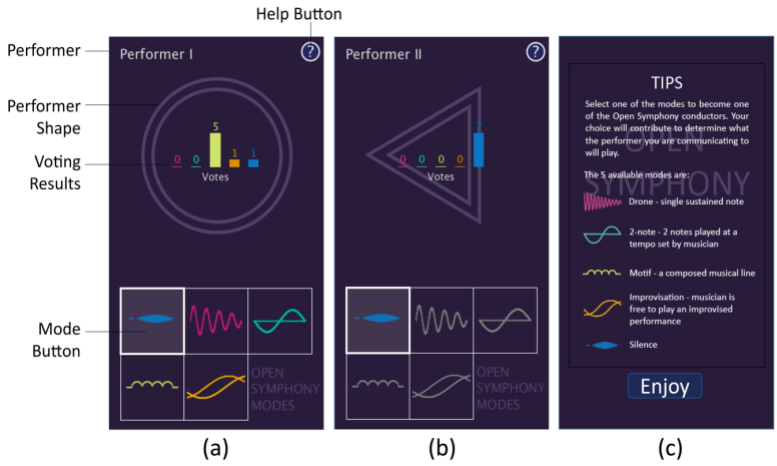


Figure 7.6 – GUI interface
[Zhang et al, 2016, p4]

Methods to investigate audience engagement

There are a variety of methods that allow us to investigate audience engagement. Examples include:

1. Self-reported questionnaires (qualitative and quantitative)
2. Interviews (mainly qualitative, focusing on open reflective responses)
3. Wearable sensors

Kraj et al. [2020, p2] make a very interesting point, that "self-reported questionnaires can only report on the conscious evaluation of affective state, whereas human affect is often an unconscious reaction". Self-reporting questionnaires after the fact are effective, but as comments are based on events from the past [ibid.], results may be negatively influenced by memory, and therefore surveys should be encouraged to be completed as soon as possible. Attempting to collect audience responses through self-reporting during an event can negatively impact the performance and therefore "skew the results" [ibid.].

The 'peak-end theory', coined by Braithwaite, Watson, Jones, & Rowe (2013), suggests that self-reporting at the end of an event will reflect an individual "most extreme peaks of arousal" Kraj et al, 2020, p5]. This supports the theory artists tend to employ when they structure a set, which peak at the start, middle and end to help enhance the spectator experience.

PANAS (Positive and Negative Effect Schedule) [Watson et al, 1988] also discussed in chapter 5.2, is a self-reported questionnaire that "considers 20 emotions, 10 positive and 10 negatives, to determine the overall emotional state of a subject", where responses can be taken at the beginning and end of a performance to capture changes in emotion [Kraj et al, 2020, p8]. Although this simple questionnaire can be used to good effect, some of the emotions listed are unlikely to provide relevant responses for some audio-visual media. For example, how does the emotion 'stronger' reflect a music performance. Nonetheless, there is potential to tailor the questionnaire to suit the needs of a given investigation.

In their investigation to "identify instrument design and performance", Lai et al [2013, p170] found that "post-performance interviews with the audience members where a valuable method". The insights offered by audience members informed their practice in developing more engaging performances [ibid.]

With regard to 'wearable sensors', this field requires specialised devices that may "be intrusive and affect the overall experience" [Kraj et al, 2020, p2]. However, "wearable sensors (can) offer a valuable alternative to self-reported data" [Shirzadian et al. 2017, p5] which can be used to support and inform existing data sets.

GSR (Galvanic Skin Response) sensors used in a number of research studies, have proved to deliver a "positive correlation between audience engagement and GSR signals" [Kraj et al, 2020, p4], in which signals correlate to the arousal level activated in each individual [Shirzadian et al. 2017, p2]. GSR has become a "'proxy' measure for audience engagement" [ibid, p3] because the technology has proven to be reliable in quantifying the audience experience [ibid, p1]. The most fascinating feature of GSR, is that collective data responses of a particular performance can identify specific moments where arousal increased, hence, artist and institutions can use this technology to pin-point the most significant moments of their event [Kraj et al, 2020, p7].

In summary, the matter of audience engagement is complex encompassing many variables that can co-exist to produce an engaging performance. This can be better accomplished by having an awareness of who your audience is and what features best reflect their

expectations. It was interesting and (totally) understandable to see that after their investigation on audience engagement, Lai et al. [2013, p173] came to the following conclusions:

1. *"Make a performance space that is visually and sonically comprehensive.*
2. *Consider showing the instruments and your interaction with it to the audience.*
3. *Consider having clearly evolving musical and performance structures.*
4. *Involving multiple performers in an ensemble setting adds contrast and dynamics to the performance"*

We can therefore surmise that the following characteristics form strategic attributes when attempting to engage an audience in a music performance, with the following points serving as guidance for this study:

1. Create a visually engaging performance space
2. Produce a welcoming environment
3. Compose and perform material that contains engaging musical features
4. Allow the audiences to draw meaning from an observable 'action-to-sound' delivery
5. Use style-specific communication, and provide relevant information where necessary

It should be added that each of these points can be subjectively interpretated by the organisers to plan and deliver the most engaging performances for their audience.

Much of the discussion surrounding audience engagement further supports the other immersive characteristics explored in this taxonomy. Proximity, envelopment, sound and visual processing, can all independently and collectively help to enhance immersivity in music performance, consequently improving audience engagement. Furthermore, the theories behind 'knowledge' support sound processing and the notion that music for an audience should be audience centred. Similarly, the 'action-to-sound' theory which relates to visual processing, further supports the significance of music cognition within live performance.

It could also be argued that proximity and the use of space can create a welcoming environment and develop engagement on the physical level, while envelopment by nature

has also been shown to improve engagement by creating unique sonic experiences. These however, point towards indirect engagement, i.e. the engagement that has naturally occurred due to the arrangement of the performance space and the appropriateness of the performed material. There are also three forms of direct engagement, 1) audience-performer interaction, 2) performer-performer interaction and 3) audience-audience interaction, with each other and the material, that require further consideration. Evidently, the concept of audience engagement is complex due to the various factors hypothesised. This chapter has highlighted some clear and useable features to be considered in the development of the projects outlined in Section C. It should be clarified that the purpose is not to 'force' various applications of audience engagement, but to consider their effectiveness on an individual basis. The goal within this study is to investigate its potential within each project.

7.6 - Summary

The listed taxonomy goes some way to realise the key research aims of this inquiry, particularly research question one. This chapter presents a comprehensive literature review to establish a clear list of immersive characteristics, whilst the primary research conducted in section C further supports the taxonomy. A strength of this research has been in the ongoing performative practice method, in which the holistic approach has permitted new problems to be investigated as they arise. These problems are clarified in the next chapter, which respond directly to research questions two and three, with the aim of informing question one. Thus, the investigations conducted through original projects have helped to shape the final list. The blended methodology applied in this study has been vital in providing such robust outcomes. Therefore, the definitive version of this taxonomy did not fully take shape until the final stages of this study when enough primary and secondary research had been conducted to make appropriate deductions.

In short, primary research indicated that sound and visual processing needed significant consideration if proximity and envelopment were to be effective. The hypothesis that such cognitive processing significantly contributes to immersivity was validated by the qualitative and quantitative data collected. The literature review presented in this chapter, positively supports the theory that both sound and visual processing occupy several characteristics that

are integral to how audiences process music, and as such, are inherent contributors to the perceived success of a musical project.

When remembering that human subjectivity should be considered advantageous in performative practice, open questions encouraged participants to provide perceptual responses. These responses across all projects continued to affirm audience engagement as a fundamental attribute for all types of music performances, particularly in new and innovative approaches. The literature review in this chapter concerning audience engagement has been validated by the opinions of participants, which in turn justify the author's initial views regarding approaches to musical composition requiring an audience-centred approach. Neither of these aspects were coherently understood during the early stages of this research, again, demonstrating how the primary research conducted in this study has been instrumental in informing this taxonomy. The list of immersive characteristics presented as a taxonomy have been clearly described in this chapter, offering a key contribution to knowledge in this field. This taxonomy provides the foundations upon which future immersive music practitioners can develop, design and deliver their projects.

The next section in this thesis provides a discussion on how original works (designed as forms of primary research) investigated the perceptive success of various immersive characteristics employed within each project. Chapters 8 through to 11 show how experimental methodologies were deployed to further understand immersivity in music performance by directly addressing the research questions.

Section C

Portfolio of Original Works

8. Project Methodology

The methodology employed for the body of work presented in this section has gone through various stages of refinement. The methodological process for this portfolio of primary research, directly responds to the investigative aims of the research questions. For instance: how can immersive characteristics be applied in original works, and how can these help to define this performance paradigm through the use of participants?

In order to address the research questions, the methodology consists of four phases, similar to common practised-based research approaches highlighted in chapter four by Fox [2003] and Candy [2006]. This approach highlights the problem that needs to be examined before a design is developed to investigate it. At the next stage, data is collected before a synthesis of outcomes is generated. The methodological process employed comprises of the following four phases:

1) Conception of original works for immersive music practice.
2) Planning and delivery of original works.
3) Collection of data against investigative aims.
4) Summary of findings and outcomes for further investigation.

Individual methodological phases have further subtopics which are outlined below. The findings of each project in the following chapters are presented in an identical methodological order for consistency.

Phase 1: Compose

A. **Immersivity**: Develop effective compositional ideas against selected immersive characteristics.
B. **Music**: Consider how the musical style, production and arrangement will complement the immersive intentions of the project.

This first phase considers the inception and development of initial ideas with regard to immersive characteristics and the suitability of the musical work. The key immersive

characteristics being investigated are discussed in chapter 7. By selecting which parameters will be employed at the initial stage of the creative process, ideas can be carefully crafted and developed to better suit the project's investigative intentions. The aim is to increase the number of immersive parameters employed at each stage of the research to reflect the experience and knowledge gained and broaden the scope of the study as it progresses. Another important factor that needs to be considered is the complex nature of music creation and the various compositional elements which contribute to the overall musical style. Therefore, it was important to create a musical identity for each project to create cohesion and continuity throughout - one which suitably reflected the immersive characteristics employed. It was also important to be sensitive to the needs and expectations of the audience by applying compositional techniques that were broadly accessible.

Phase 2: Plan & Deliver

C. **Performance Space**: Carefully select and plan the performance to be delivered in a suitable space.
D. **Delivery Format**: Creatively arrange the performers, loudspeakers and audience, within the selected performance space to suit the investigative aims of the project.

The second phase considers the use of space and the potential delivery formats that are suitable for the exploratory intentions of each project. It is important that factors such as shape, size, seating and room acoustics are considered when choosing an appropriate performance space. It is unlikely the performance environment will be perfect, and so, it is essential to ensure that the sonic and practical characteristics of the space do not diminish the immersive characteristics of the project. The delivery format is equally crucial and demands that key creative decisions are made with regard to the arrangement of performers, loudspeakers, and audience members withing the listening space - thus allowing the planned immersive characteristics to be suitably explored against the project's investigative intentions.

Phase 3: Capture Evidence

E. **AV content**: Plan effective methods to capture audio-visual content as evidence.

F. **Questionnaire**: Carefully formulate questions to capture valid and reliable participant responses against each project's investigative aims.

The third phase focuses on the collection of appropriate evidence to inform the outcomes. Particular importance is placed on the participant questionnaires, which were devised to help better understand the effectiveness of the immersive characteristics employed from the audience's perspective. Each project investigated different methods of employing immersive characteristics, and therefore, it was vital that questionnaires were formulated with this in mind. It was also important that the questionnaires were easily accessible with regard to format, presentation and language (which does not use difficult terminology), to increase audience participation. The questionnaire seeks to extrapolate quantitative data to provide an overall score for different performance features, as well as qualitative data to objectively broaden understanding of how audiences perceive immersivity in music performance. Thus, the formulation of each questionnaire considers the following queries.

a) What questions must be included to effectively capture valid and reliable responses against the project's investigative aims?
b) What format, structure and language can be used to ensure effective audience participation is captured in a timely manner?
c) How can quantitative and qualitative data be collected to provide a greater depth of inquiry?

Phase 4**: **Synthesis & Outcomes

G. **Collect & Collate:** Gather and organise audience responses.
H. **Summary**: Synthesise audience responses, highlighting the positive and negative features of the project.
I. **Outcomes:** Outline successes and areas for development against the immersive characteristics the project employed.

The final phase seeks to investigate the overall perception of the project in its application of immersive characteristics. This is the key aim of this research, which helped to determine what 'immersivity' means conceptually against the literature review and from the audience perspective (RQ 1 & 3). The outcomes should also indicate how immersive parameters can be

effectively employed in different performance environments (RQ2). The following approach will examine each project to inform the research questions (chapter 1).

a) How will data be collected and organised with clarity?
b) What conclusions can be deduced from participant responses on the overall quality of the work and the effectiveness of the immersive characteristics applied?
c) What points can be surmised that identify key positive and negative characteristics that must be considered going forward?

The most pertinent data originated from the audience's responses on the effectiveness of the various immersive parameters employed in each project. Furthermore, the audience's subjective responses of what immersivity is in music performance, as well as any suggestions offered, aided to clarify their expectations of this performance medium. The data collected allowed a better understanding of the various intrinsic characteristics required to create innovative and unique listening experiences with immersivity in mind.

9. Project 1: 'NOVA NEON'

This chapter outlines the first project's aims and methodology in employing immersive characteristics in a music performance. It then discusses how evidence was captured and disseminated, before highlighting positives and negative outcomes that can better inform future projects. These outcomes were reflected against the research questions and literature review.

9.1 - Aim

The aim of project one was to improve this study's key understanding of immersivity in music performance, by gathering information from audience members on the effectiveness of the immersive parameters employed.

The intention was to begin investigating how compositional and spatial parameters can be devised to explore immersivity in music performance in the simplest possible manner. Thus, a limited number of elements were considered to reduce the number of variables tested against the research questions. A small room utilising an acoustic ensemble performing popular music without a sound reproduction system was chosen. At the most fundamental level, the project was planned to implement the following aspects in no particular order:

- apply immersive parameters such as proximity and envelopment
- engage the audience in the music material using contemporary music techniques
- ensure that the musical material is clearly audible
- experiment with the arrangement of the performance space to investigate the effectiveness of different delivery formats

9.2 - Methodology

Phase 1: Composing

A. **Immersivity**:

The performance space was selected to replicate an intimate event and create a level of inclusivity for all audience members. This, in addition to the composition of popular original music performed in a 'homely' environment, was hoped to enhance proximity and audience engagement, whilst also helping to investigate how the performance arrangements will create a sense of envelopment. It should be highlighted that at this stage, the list of immersive parameters outlined in this paper (chapter 7), had not been clearly established at the time this project took place, so elements such as audio and visual processing had not yet been fully considered. It is the evidence gathered by this project that established their importance.

B. **Music**:

Due to the intimate space and the intention of minimising performance elements, the music had been composed so that no sound reproduction system such as a PA was required. The material was composed using popular music structures and arranging techniques, comprised of simple but engaging melodic, harmonic and rhythmic elements, so that the material is more appealing to general audiences, without previous knowledge required. The songs were approximately 3 to 5 minutes in length, with simple instrumentation and limited embedded production techniques. A 5-piece ensemble was assembled which included drums, bass guitar, electric guitar, acoustic guitar, keyboard, lead vocal and three backing vocals. Some adjustments needed to be made to the ensemble to ensure that volume remained balanced against the un-amplified vocals and acoustic guitar. The drums used only a light snare, with brushes or rods, and the snare case was used as the kick drum, whilst a tambourine was used for high frequency content. The keyboard, bass and electric guitar used small amplifiers at low levels (in fact the keyboard was amplified through a small Bluetooth speaker), that accurately represented the timbral characteristics of the instrument with plenty of amplitude headroom. Rehearsals took place in the performance space itself, allowing for appropriate

adjustments to be made to the overall balance, ensuring that the vocals remained audible. The set comprised of six songs running at approximately 25 minutes in length in the following order:

1. Lights Out
2. In a Little While
3. Blue Line
4. For Your Eyes
5. Fighting for It
6. The Citizen

Phase 2: Planning & Delivery

C. **Performance Space**:

A small room approximately the size of a regular living room, rehearsal room or small live studio room, with the capacity of approximately 15 audience members was used. The space was the first to be selected and therefore directly influenced the musical style and instrumentation of the compositions, as well as the potential delivery formats.

D. **Delivery Format**:

The project was designed to test the effectiveness of the composed material in three different delivery formats, where the musical material and the size of the space remain constant, but the arrangement of the musicians and audience members changed. The variations in delivery would therefore allow for the collection of information on how effective each arrangement was in creating an immersive environment for the audience against proximity, envelopment and audience engagement. Due to the small size of the space, the proximity between the audience and performers created an intimacy that would be relevant for all three delivery formats.

All three concerts took place on the same evening with three different audiences. It was important that audiences where new to the material, so that their perception of the performance was not influenced by knowledge of the repertoire, and a pre-determined

expectation of how it should be delivered. The absence of a loudspeaker system meant that the sound sources emanated directly from the musician's positions. To ensure that the localisation of each sound-point was not affected (beyond the natural reverberation of the room), any amplification used directly reflected the position of that instrument (small speakers were used to amplify the electric guitar, bass and keyboard from the performers position). The three different delivery formats and their order of performance were:

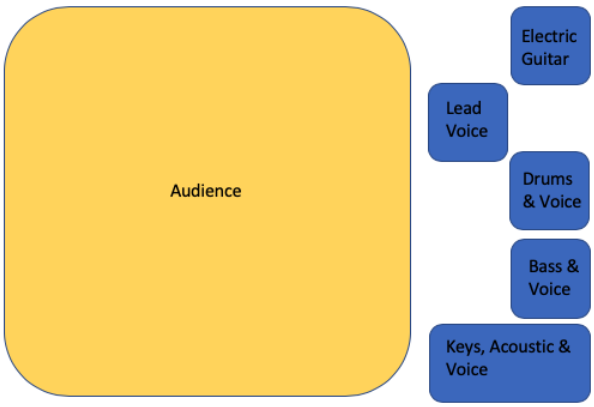


Figure 8.1

1.Traditional – This delivery format was designed to reflect common practice, experienced in most event spaces, in which performers and audience members are separated as a front and back model (figure 8.1). The audience and performers would have full view of each other within their peripheral vision.

2.Triangles – This delivery format would experiment with the space by splitting the audience and performers into two groups (figure 8.2). The intention was to deviate from the traditional format whilst ensuring that both groups retained full view of each other in their peripheral vision.

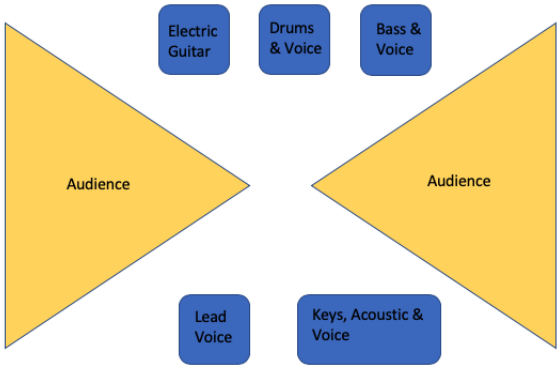
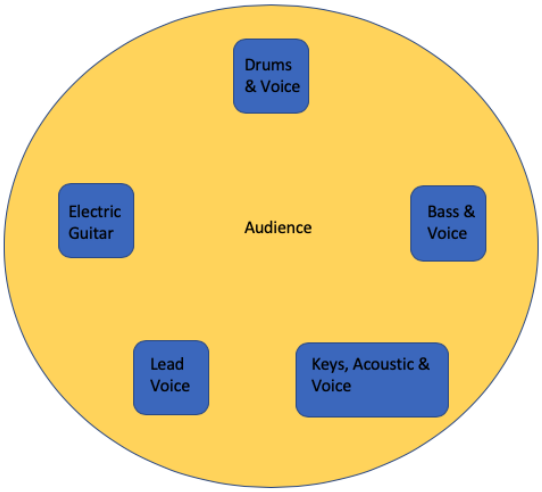


Figure 8.2



3. In-The-Round – This delivery format would further experiment with the space by arranging the performers in a circular pattern, with the audience permitted to sit anywhere they wished within the circle in a fairly informal manner (figure 8.3).

Figure 8.3

Phase 3: Evidence

E. **Audio-Visual Content**:

<u>Images</u>

Figure 8.4 - Traditional

Figure 8.5 - Triangles

Figure 8.6 – In-The-Round

Audio

The performance was captured using an Ambeo soundfield microphone and processed into a binaural stereo file using the techniques discussed in chapter 2.3. The microphone was placed in a static position in the room above the audience and musicians to capture all three performances. No changes were made to its position and gain levels throughout all three concerts.

Video:

The performance was captured using two static GoPro cameras each mounted to an adjacent wall. The videos listed below for each performance were edited to present the room in split screen (where possible), using both camera angles alongside the binaural recording. The use of headphones for listening is advised for best results.

The performance for each of the arrangements discussed can be viewed at the following links:

- Traditional
- Triangles
- In-the-round

Note: Due to some issues experienced with the GoPro, the Triangles *performance does not include the final song of the set, whilst the* In-The-Round *video only includes one of the 2 viewpoints.*

F. **Questionnaire**:

The questions were formulated to ensure that participants could inform the investigative aims of this project against the immersive parameters employed. They were also formulated to ensure questions were easy to understand and answer, without the use of difficult technological language. Open and closed questions were used to allow for the collection of quantitative and qualitative feedback. The first part of each question could be answered on a Likert scale of 1 to 5 (quantitative). The second part would allow individuals to reflect and comment more freely on each topic (qualitative).

The questions were:

1. Did you find the performance engaging? *(Score 1 – 5)*
2. What elements did you find engaging or not engaging?
3. Could you hear the music clearly? *(Score 1 – 5)*
4. If not, why do you think that is?
5. How would you rate the overall sound quality? *(Score 1 – 5)*
6. In your own words, please describe why the sound was of poor or good quality.
7. How well could you see all the performers? *(Score 1 – 5)*
8. If not, why was that the case?
9. How well do you think the space was used for this performance? *(Score 1 – 5)*
10. Are there any particular reasons why you liked or disliked the way the musicians and audience were arranged in the space.

11. Which of the following comments best captures the idea of 'immersion' in a performance?
    i. The sound is coming from multiple directions
    ii. The performers use all of the space
    iii. The audience is close to the performers
    iv. The performance space has been used to enhance the musical material

12. How immersive was the event for you? *(Score 1 – 5)*

13. What could have made it more immersive in your opinion?

- In the scored questions, 1 represents a low score and 5 a high score, allowing audience members to pick which score best reflects their opinion.
- *Questions 1 & 2* were used to establish if the music was engaging. Although this does not directly support the research with regard to immersive elements, it was important to see if there was a relationship between the quality of the performance and the level of immersion.
- *Questions 3 & 4* were needed to establish if these delivery models had an effect on the clarity of sound, allowing audience members to clarify why sound clarity was affected.
- *Questions 5 & 6* were used to establish if there were any issues with timbre or balance, by using simple terms such as 'sound quality' whilst allowing audience members to explain any issues.
- *Questions 7 & 8* are important to establish quality of visibility for each delivery format.
- *Questions 9 & 10* allow the audience members to express their opinion on the use of space, such as the arrangement of the audience and performance.
- *Question 11 to 13* have been used to determine the quality of the immersion. Q11 provides the audience with some insight on what 'immersion' may mean in music performance from their perspective, before scoring their objective opinion on the level of immersion in Q12. Q13 allowed audience members to provide suggestions that this research could potentially use for future projects.

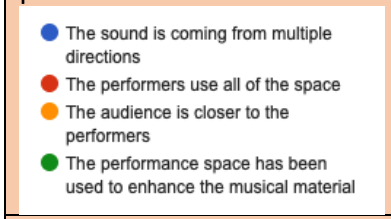
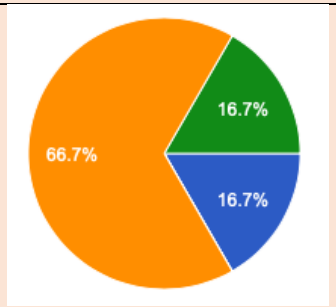
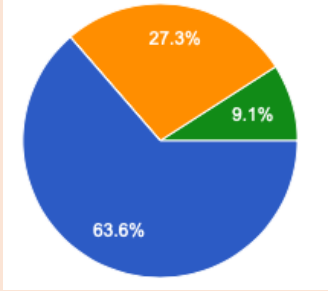
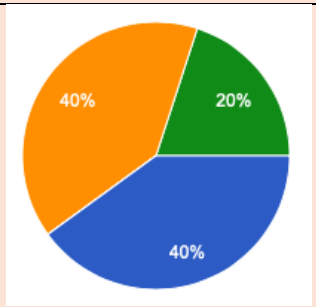
Each group of participants for each setup was sent the questionnaire using Google Doc after the performance. The audience was encouraged to completed this at their earliest convenience during the performance and via email.

Phase 4: Synthesis & Conclusions

G. **Collect & Collate**

The table below summarises participant responses to the questionnaire. The three difference audiences which participated for each performance ranged in age from early 20s to late 60s, with the majority of the audience in their 20s and 30s, whilst both genders were proportionally represented (18 male, 20 female). The *Traditional* format yielded 12 responses, Triangles - 11, and In-the-round – 15, directly responding to the audience number that attended each event, meaning that all participants responded to the questionnaire. The majority (over 50%) did so within 24 hours. However, three participants in all took about a week to complete the questionnaire, whilst one participant took ten days.

Delivery Format	**Traditional** (12 responses)	**Triangles** (11 responses)	**In-The-Round** (15 responses)
1.Did you find the performance engaging?	Average score = 4.75	Average score = 4.82	Average score = 4.73
2.What elements did you find engaging or not engaging?	The audience found the performance engaging, sighting the quality of musicianship, songs and proximity as the key elements.	Engaging - proximity, sound quality, harmonies, surround sound Unengaging - the spread meant there was a lack of focal point and a lack of visibility unless you turn your head, therefore more challenging visually	Engaging due to the proximity, performance, arrangement, sound balance, surround sound, harmonies and informal nature. Unengaging due to the restricted view.
3.Could you hear the music clearly?	Average score = 4.91	Average score = 4.73	Average score = 4.8
4.If not, why do you think that is?	Some minor balance issues	A lack of vocal balance	Lead vocals not perfectly balanced with the group
5.How would you rate the overall sound quality?	Average score = 4.75	Average score = 4.64	Average score = 4.67
6.In your own words, please describe why the sound was of poor or good quality.	Excellent balance overall Snare a little too loud	Some balance issues, especially with the clarity of the vocals	Fantastic feedback on the quality of the sound
7.How well could you see all the performers?	Average score = 4.75	Average score = 3.55	Average score = 3.53
8.If not, why was that the case?	Some minimal lack of visibility due the guitarists being behind the lead singer at some points.	Major issue with the band split into two meant that visually the audience had to physically move their heads to see the actions of each musician	Issues with visibility due to the nature of this model
9.How well do you think the space was used for this performance?	Average score = 4.67	Average score = 4.55	Average score = 4.47

10.Are there any particular reasons why you liked or disliked the way the musicians and audience were arranged in the space.	The setup in the space was ok, not entirely comfortable and well arranged, whilst audience members felt exposed due to the intimacy and proximity.	Liked due to the unusual and unique setup, with the main positives being the stereo model and proximity, however the arrangement poses real issues with visibility	Very positive comments with regard to intimacy. The issue with visibility persists.
11.Which of the following comments best captures the idea of immersion in a performance? 			
12.How immersive was the event for you?	Average score = 4.25	Average score = 4.73	Average score = 4.67
13.What could have made it more immersive in your opinion?	Visuals, multi-directional audio i.e. envelopment, better audience communication from the musicians, surprises in the performance.	Additional visual aspects would have added to the overall affect.	Audience participation, lights (additional visuals), remind people to not use their phones to limit distractions and swivel chairs to increase visibility

H. **Summary**:

This section outlines participant responses from the questionnaire for each performance.

Traditional: Other than some minor sound balance issues, the traditional version produced the best visibility and sound quality. This helps to cement the reasons why historically this particular front-back format has been used so widely, as the audience can see all of the performers whilst there is also effective spatial separation of the voices and instruments. Furthermore, from a performer's perspective, the proximity to other musicians means that there is effective musical cohesion. This is because it is easy to hear and see other performers, providing better musical communication. This model however, scored the least in immersivity, likely due to reduced levels of proximity and the lack of envelopment. A key aim of this study is to explore delivery methods that do not conform to this conventional model, hence, the following two formats:

Triangles: This setup provided some very interesting results. It scored the highest in immersivity due to the dual-directional sound and the improved proximity to the musicians. It also included more positive comments on the level of engagement, likely due to the unusual setup. However, it scored very low on visibility, where the segregated spread of musicians lacked a focal point. Many audience members commented on the negative effect this had on the overall performance, as they needed to constantly move their heads and rotate their bodies to focus on different performers. From the performer's perspective, this format also created a separation issue, where unamplified voices and no monitoring system made it more difficult to hear each other, therefore affecting the accuracy and quality of the performance.

In-the-Round: This format scored the lowest in visibility due to the informal seating arrangement, which restricted visibility for some audience members by finding themselves too close to some musicians and other participants. However, this informal arrangement increased proximity for both audience and performers, and therefore positively impacted intimacy, inclusivity and audience engagement. It also improved visibility for the performers, as it reflected how musicians tend to naturally rehearse by facing inwards, thus improving

physical communication between them, which may have enhanced audience enjoyment. Although all formats scored high in quality of sound, this particular format produced the most positive comments on the overall quality of immersivity. The increase in envelopment on the horizontal plane is likely to be the contributing factor. As with the Triangles format, this setup also created a separation issue for the performers, but to a lesser degree.

I. **Outcomes:**

This project has provided this study with usable and relevant information against the immersive parameters employed. The purpose was to investigate proximity and envelopment, with both characteristics used as a vehicle for audience engagement. Key points for consideration are listed below, which examine the projects effectiveness against the research questions on immersivity in music performance. The outcomes have been summarised in relation to the participant questionnaire, with key points outlined for further investigation in future projects.

- **Audience engagement –** Participants highlighted that the quality of musicianship and songs were directly linked to their engagement with the performance. Their proximity to the performers, the informal intimacy of the environment and use of the space further enhance their enjoyment.

- **Sound balance** - All formats suffered some issues in sound balance, in particular the lead vocal lacking impact and clarity. This was a realistic issue that would likely occur due to the absence of a loudspeaker amplification system. Regardless of the delivery format, steps must be made to ensure better sound quality distribution.

- **Visibility** – The more immersive delivery formats such as *Triangle* and *In-the-round*, reduced the quality of visibility, and therefore the visual processing of the musical material. As both projects implemented an informal seating arrangement, a formal seating plan that can accommodate better visibility results must be considered for future projects of this nature.

- **Immersivity** – The more experimental formats, *Triangle* and *In-the-round*, scored well for immersivity, potentially due to the enhanced levels of proximity and envelopment explored by these delivery formats. Consequently, both proximity and envelopment were deemed as the most important characteristics in the employment of immersivity for music performance.

- **Participants recommendations**

The audience emphasised that musicians should engage more with the audience using verbal communication. As explored in chapter 7, this is an integral function of music as a mode of entertainment. Additionally, it provides the audience with knowledge for music material that has been previously unheard. Thus, this study must consider how the theory behind knowledge through the medium of communication can be further explored. It should be noted that as with sound and visual processing, audience engagement had yet to be linked to immersivity in music performance.

Audience members recommended possible additions that could potentially improve immersivity, such as audience participation, additional visuals and surprise moments. All of these are relevant points which can be considered for future study.

Questionnaire - It is clear from the timecode produced by the survey that more effort needs to be made to ensure participants complete the questionnaire in a timely manner, preferably as quickly as possible after the completion of the event.

This project highlighted that both proximity and envelopment are key immersive characteristics, corroborating what had been learnt from previous studies discussed in the literature review. However, it has also highlighted the issue of sound and visual processing when experimenting with non-traditional delivery formats. Because both of these are fundamental methods in which we process and give meaning to musical material, they needed to be considered for future investigative projects in this study. This outcome also corroborates past papers on the importance of sound and visual processing as integral features of music performance, with particular linkage to sonic intelligibility and gesture.

Moreover, this project emphasises the essential role such cognitive processing plays in immersive music practice where non-traditional delivery formats are utilised.

Participant responses demonstrate that the musical material and its performance had been effective regardless of the delivery format. However, for best results when intending to create an immersive music environment, the 'in-the-round' format is recommended, but it should be implemented with a formal seating plan within the performance space that considers audio-visual aspects from the audience's perspective.

The aim is to attempt to improve these parameters in any given space, by limiting any issues that may arise with sound balance and reduced visibility. The nature of the musical work could be effortlessly realised in any small informal space to ensure proximity and intimacy are captured appropriately. Some care needs to be made to ensure the lead vocal is heard, therefore rehearsals should take place in the performance space with the same delivery format for best results. Levels could be adjusted appropriately, even though the presence of an audience will likely affect any balance decisions made prior to the performance. It could be considered that the lead vocal be amplified (one microphone and small speaker at the performers position), but it is the authors opinion that this would negatively impact the spectacle of the indented informal and organic performance environment.

10. Project 2: 'ONLY HUMAN'

This chapter outlines the second project's aims and methodology in employing immersive characteristics in a music performance, having considered the outcomes from the previous project's investigations. It then discusses how evidence was synthesised to provide usable information against the research questions, outlining what further immersive characteristics need to be explored in future projects.

10.1 - Aim

The aim of project two was to further develop this studies knowledge and understanding of immersivity in live music performance, by considering the advantages and limitations verified in project one, whilst also exploring further possibilities.

The key positives outlined in project one are on the advantages of proximity and envelopment as immersive characteristics, which intrinsically also contributed to audience engagement. The audience's perception of immersivity was also enhanced due to the unique experimental delivery formats, contributing to the audience's enjoyment. However, these experimental formats also stressed the importance of audio-visual processing as integral factors, where both elements were negatively impacted by the arrangements. Some of the participants recommendations were also considered for greater audience engagement.

When planning this project, the following investigative intentions were outlined in no particular order of importance:

- To ensure proximity and the sense of intimacy remained a key factor in the delivery
- To ensure good sound quality across the sounding space whilst improving envelopment
- To greatly improve the level of visibility for all audience members
- To implement spatialisation techniques such as the movement of sound sources
- To add elements of surprise which act as audience engagement

- To improve the audiences understanding of the event through visual aids and verbal communication

Although not directly linked to this study's investigative aims, it was noted from the previous project, that more could be done to encourage participants to respond to the survey in a timely manner.

9.2 - Methodology

Phase 1: Composing

A. **Immersivity**:

Compositional ideas for this project to further investigate immersive characteristics in music performance drew guidance from the knowledge gained from project one. Firstly, the intention was to continue to deliver music without a loudspeaker system at this stage, and therefore it was important that the performance space was not too large, whilst selecting and composing for an ensemble that would suit the chosen space. Secondly, the study would continue to experiment with the arrangement of the performance space so that envelopment was a key feature, but with the caveat that visibility needed to be improved for all audience members. Thirdly, the arrangement of the space needed to also consider sound quality, ensuring that instruments were balanced within the listening space. Finally, moments of surprise and movement of sound sources would be embedded to enhance audience engagement.

B. **Music**:

A contemporary fusion ensemble was chosen comprising Drums, Bass, Piano, a String Quartet and a Mezzo-Soprano Voice. The musical style blended modern Jazz with ambient cinematic elements, drawing influence from artists such as Cinematic Orchestra, GoGo Penguin and Max Richter. The music was arranged so that it involved plenty of repetition, so that the main focus would be on the 'grooves', the overall ambience, key melodic phrases, with variations in texture and dynamics to create development. The intention was to assemble a group that

suited the size of the space, whilst shifting away from popular lyric based music employed in project one, allowing for the implementation of some movement in the space. Instrumental parts had been written so that the string players and the voice could use movement within the performance to enhance immersivity. The organisation of any movement was planned based on the architectural characteristics and performance arrangement of the space. Rehearsals took place in the performance space which permitted the sound balance between instruments to be modified, whilst allowing any movement to be practiced in the space. The table below outlines the track order along with any movement of performers and surprise moments for each piece.

Track Order	Movement & Surprise Moments
1. **Senescence**	The piano to start with each musician to enter the room from the corner behind Camera 1 (see figure 9.1) in the following order: 1.Cello to enter and sit, then start playing after 16 bars. 2.Viola and 2nd Violin to enter playing after 8 bars. Viola to walk directly to the right and sit. 2nd Violin to walk up to the drums, enter the middle of the floor before sitting down. 3. 1st Violin to follow shortly after, walking past the drums, then entering the middle of the floor before sitting down. 4.Drums and Bass to wait until all string players are sat before entering the room.
2. **24**	No Movement
3. **Hyperfocus**	Voice to enter the room from behind Camera 1 for section A, walk up to the drums and enter the middle of the room, then carry on to the corner behind Camera 2. For section C, voice to perform from the middle of the floor next to the piano.
4. **Contact**	No Movement
5. **Inhale**	A surprise moment will be created by Piano 2 playing the main theme of the piece in a higher register to finish the performance. This will make audience members recognise a new instrument sound from a different location heard for the first and only time. As an additional surprise, the unsuspecting audience will notice that the part is being played by another audience member, who will move from their seated position to Piano 2 in the final stages of the piece.

Phase 2: Plan & Deliver

C. **Performance Space**:

It was important for this project to increase the size of the space utilised in project one to further explore the effects of proximity and audio-visual processing. A small performance hall was selected, which permitted the use of a larger ensemble and seating arrangement, thus moving slightly closer to a commercial setup. The selected space provided an appropriate level of reverberation that was not too dry, suitable for the assembled ensemble. As no sound reproduction system would be used, it was essential that the size and arrangement of the space was considered, ensuring that the sound quality would remain balanced within the listening space.

D. **Delivery Format**:

The intention was to create a delivery format that embedded immersive elements such as proximity and envelopment, whilst retaining key performance elements such as visibility and sound quality. The delivery format was therefore designed so that all audience members were close to performers with sound emanating from multiple directions, whilst ensuring full view of the ensemble within their peripheral vision. Other matters highlighted by the evidence gathered in project one also needed to be considered. For example, an increase in proximity means a possible reduction in visibility depending on listening position. Inversely, an increase in visibility by moving audience members further back, reduces proximity and sound quality when a sound reproduction system is not used. A speaker system was not employed with the purpose to retain the natural sonic qualities of the space and instrumentation, whilst allowing musicians to move freely. Moreover, a speaker system (front-of-house and monitors) would add another complex layer of parameters that would need to be controlled, such as additional reverberation and timbral characteristics, whilst it would not fully reflect the ensemble and musical style.

The floor plan below (figure 9.1) illustrates how the performers and audience members were arranged in the room. The hexagonal shape with six segments was designed to fulfil the

delivery criteria mentioned above. Audience members should be able to see all three musical groups to either side of them, as well as in front, in hope of resolving the issue of visibility (this stands true for the performers also). It was originally proposed that a tiered seating plan be applied, but unfortunately appropriate resources were not available. In addition, this shape should provide a good level of proximity to (some but not all) performers, whilst ensuring a good sound balance and visual processing of physical action. Finally, lanes between segments allowed musicians to move within the performance space during specified moments, as highlighted in the table above.

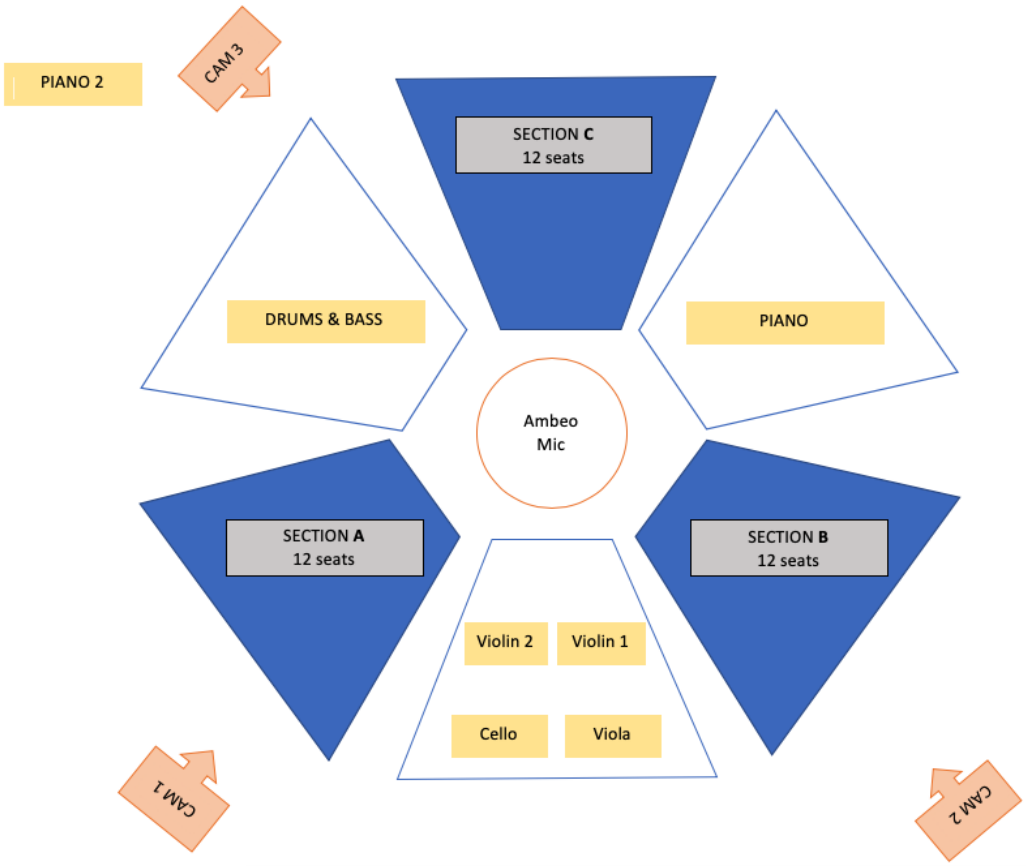


Figure 9.1 – Floor Plan

Phase 3: Capture Evidence

E. **AV content**:

Image:

Figure 9.2 illustrates the setup of the performance space as indicated in Figure 9.1 pre-concert. The instrumental groups are clearly visible as are the three segments with 12 seats in each. The Ambeo mic is place in the centre of the performance space and the lanes are wide enough for the musicians to walk along them.

Figure 9.2 – Performance Space

Audio

A Sennheiser Ambeo soundfield microphone placed in the centre of the room, was used to capture an audio recording, which was later processed into a Binaural stereo file.

Video:

Three static GoPro cameras indicated in Figure 9.1 as Cam 1, 2 & 3, captured the performance. A video using the GoPro footage was edited with the binaural track and can be viewed here.

F. **Questionnaire**:

As in project one, the audience questionnaire comprised qualitative and quantitative methods. Some questions allowed for a score to be given between 1 (low) and 5 (high) using

a Likert scale. Other closed questions required an answer of ‘Yes’, ‘No’ or ‘Maybe’. Open questions allowed audience members to provide their personal perspective and opinion more freely.

This questionnaire aimed to make the questions clear and specific for better responses. Similar questions used in project one on sound quality, visibility, use of space and musical engagement remain, with additional questions on proximity and movement to assess the success of those characteristics.

An additional component was added in the questionnaire to further improve our understanding of audience perception and enjoyment. Seats in each section were numbered, with a programme flyer provided on each seat, as indicated in Figure 9.3 below. Each audience section contained 12 seats, with seat numbers ranging from A1 - A12, B1 - B12 and C1 - C12. The opening survey question requested audience members to log their seat number. This would hopefully provide further clarity on positive and negative elements that may arise due to specific seating positions, in particular visibility, sound quality and proximity. The flyer also provided an added bonus of providing the audience with the track order. The musical director (the author) also spoke to the audience at integral moments during the performance, to provide details about the project, the music, the performance arrangement and the musicians – thereby engaging directly with the audience and improving knowledge.

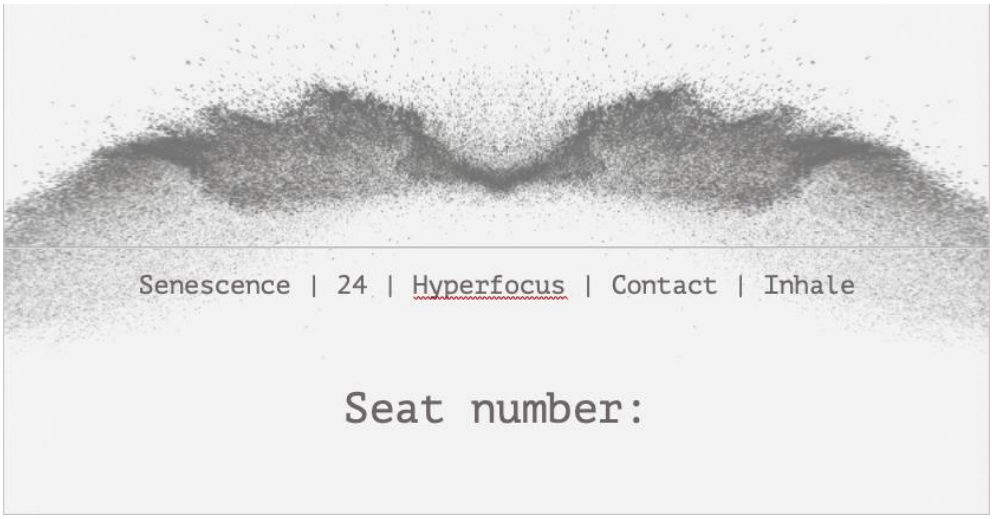


Figure 9.3 – Seat Number Flyer

Finally, it seemed pertinent that the musicians also had the opportunity to reflect and provide their opinion on this type of performance and delivery format. A performer questionnaire was therefore also formulated. Both questionnaires were made available using Google Docs and circulated prior to the performance. Both groups (performers and audience) were reminded and encouraged to complete the survey at their earliest opportunity, at the end of the event and as a follow up email the next day.

Phase 4: Synthesis & Conclusions

G. **Collect & Collate:**

The two tables below display the results of the performer and audience questionnaires. These are followed by a summary which outline the advantages and disadvantages of this project with regard to its application of immersive characteristics, both from the audience and performer perspective. Key discoveries are then summarised to support and inform the objectives of the next project. The questionnaire yielded 29 responses from a possible 32 participants. Gender was proportionally represented (17 male, 15 female), with the age of participants ranging from late teens (18+) to late 60s. Almost all participants completed the questionnaire within 48 hours, but 2 participants took almost a week to respond. Five of possible six performers responded, three within 48 hours and the other 2 within four days. The performers, minus the author, consisted of four males and two females.

Performer Questionnaire	
1. Did the setup of the space effect your ability to hear the other musicians clearly? If so, why?	The responses generally comment positively on the setup. Some performers felt that the distance did impact their ability to hear other musicians, however, this was minimal.
2. Did the setup of the space effect your ability to see the other musicians clearly? If so, why?	All the musicians commented positively on the visibility of other musicians. However, the violinist did find that the piano obstructing the pianist was an issue when trying to be rhythmically in sync during sections that did not include the rhythm section.

3. Did the setup of the space effect the quality of your performance? If so, why?	A divided opinion showed that 1. It did not affect their performance 2. It did because they had to focus more to hear the other musicians
4. Do you think that the setup and movement of the performers offer the audience a more immersive experience? If so, why?	A resounding yes, due to the unique setup which offered movement, envelopment and most of all the intimacy produced by the proximity.
5. What could have been done to make the performance more immersive?	• More movement • Audience participation • Movement of the audience

Audience Questionnaire	
1. Did you enjoy the music? *(Score 1 - 5)*	Average score = 4.9
2. What elements from the performance engaged your attention?	Movement yielded the highest mentions (8), with elements such as the unusual surround sound setup, the string quartet and operatic vocal mentioned many (4/5) times, whilst the surprise piano was mentioned twice.
3. What elements from the performance did not engage your attention?	Various comments including specific instruments such as the drums, bass, cello and viola.
4. How clearly could you hear the music? *(Score 1 - 5)*	Average score = 4.7
5. If you couldn't hear clearly, why do you think that is?	Some instruments could not be heard enough. Seat numbers show that this is usually when an instrument is further away from the listeners position. For example, the cello was sometime inaudible for Section C, and the piano for Section A and some members of Section B.
6. How would you rate the overall balance of the instruments? *(Score 1 - 5)*	Average score = 4.4 4 received the higher percentage rating (58%), followed by 5 (39%) with one audience member rating the overall balance a 3 (seat B1). This audience member highlighted that their position so close to the strings masked the other instruments.
7. In your own words, please describe why the instruments were well balanced or not well balanced.	• The general response is that the balance was very good considering the setup • Instrument groups opposite audience groups were least heard • Audience sat next to instruments found those a little too loud • The separation did provide some clarity • Several comments on the piano being too quiet • The drums were too loud in some of the pieces
8. How well could you see all the performers? *(Score 1 - 5)*	Average score = 3.9 2 rating (6.5%), seat B7 experienced poor visibility due to the piano 3 rating (16%) 4 rating (55%) 5 rating (22.5%)

9. If you could not see the performers very well, why this was?	• The Cello & Viola were obstructed because they were behind the violinists. • The pianist was obstructed by the piano itself for members of section B, whilst those in section C could only see the pianist sideways on. • Some audience members complained about having to make small movements with their heads to see musicians to their left and right
10. How effective do you think the audience layout was for this performance? *(Score 1 - 5)*	Average score = 4.6
11. Are there any particular reasons you liked or disliked the way the musicians and audience were arranged in the space?	• Positive comments on the inclusive nature of the setup, making the audience feel that they are inside the performance. • The direction of audio from multiple locations made it more immersive • Proximity and intimacy made it more personal and engaging • Being able to see the musician's emotions close up • An audience member commented on how this inclusive delivery model created a level of equality between the audience and performers
12. Did you feel sufficiently close to the performers? *(Yes, Maybe or No)*	Yes (90%)
13. Did the unusual setup of the audience and performers enhance your experience of the concert? *(Yes, Maybe or No)*	Yes (97%)
14. Did the movement of the performers enhance your experience? *(Yes, Maybe or No)*	Yes (90%)
15. How immersive did you find the concert? *(Score 1 - 5)*	Average score = 4.7
16. What could have made it more immersive in your opinion?	• More Surprises • More Movement (this score the highest responses) • Improvement in visibility • Audience participation • Performers in the audience • Audience changing seats and/or allowed to move

H. **Summary**:

The section summarises the participants responses from the questionnaire, outlining audience perception against the specific immersive characteristics employed.

Movement: The embedded movement scored very highly with 90% commenting on how it enhanced their experience. It may have been appropriate to compose more parts with movement, however, such performance characteristics must be approached with great care so that the overall effectiveness of the music is not negatively impacted, where too much movement can potentially affect compositional integrity. It is worth noting that from this experience movement possesses two challenges. The first is that parts need to be simple enough for performers to be able to play them accurately whilst simultaneously moving. The second relates to sonic balance, where any movement will change how audible that part is to both the audience and other musicians - the latter being quite problematic if no monitoring is available for the performer.

Proximity: Considering that the arrangement was augmented to ensure that all of the musicians and audience fitted within the circle and segments, it was interesting to note that the proximity of the setup scored highly (90%). The unusual setup of the performance space yielded a very positive response, with 97% of participants agreeing that it enhanced their overall experience. Audience members seemed to enjoy the intimate arrangement, where closeness to the musicians created a sense of inclusion; one in which the audience felt “equal” to the performers.

Visual Processing: Although proximity adds an immersive element to the music, it can produce adverse issues regarding visibility and sound quality. The cello and viola were unfortunately hidden behind the violins and therefore could not be seen by small parts of the audience. It would have been beneficial to arrange the string ensemble so that all the players were visible. There was the possibility of arranging the string quartet in the traditional shape of a semi-circle, which is beneficial to the musicians as they can see each other and easily follow direction cues. However, this meant that some performers would have their backs

turned to the audience, thus the seating arrangement indicated in figure 9.1 was selected. Additionally, the piano limited the view of those sitting next to it, whilst other audience members limited the view of those in the back rows. The original idea of using a tiered seating plan would have resolved some of these issues. Many of the problems of visibility became evident from the numbered seating plan which highlighted the issues some audience members experienced.

Sound Processing & Envelopment: The direction of sound from multiple positions including movement, was positively received by the audience. As with visual processing however, the position of each audience member determined their experience of sound quality - whether they were either too close or too far from performers. Those too close to instruments such as the drums or strings, could not clearly hear other instrumental groups as they were masked by the energy and amplitude of those closest to them. Sections of the audience perceived poor sound balance against instrumental groups opposite them, such as Section A against the Piano, and Section C against the Strings. This was a similar issue for the performers, who struggled to hear the instruments furthest away from them, requiring a continuous focus to perform with accuracy. Such problems occurred when there was no drum part keeping time and string players had to focus on the piano for timing accuracy.

Audience Engagement: Although this project highlighted many elements that require further consideration and refining, it was interesting to discover that the audience did not perceive these issues unfavourably, and did not seem to affect their general enjoyment of the performance. Participants found the compositional material, delivery and arrangement of the space to increased their sense of 'immersion', regardless of the problems mentioned. It is worth noting that the unusual ensemble, which included a string quartet and operatic vocal, enhanced the audience's experience, possibly due to their lack of exposure to such instrumental groups. It was also commented several times that the surprise entrance of pianist was a worthwhile addition to the performance, which is likely to have made them more aware of the space and its sonic qualities.

I. **Outcomes:**

This project highlighted some relevant pros and cons when trying to create an immersive music performance environment. It verified some of the deductions arising from the first project, whilst providing further information on immersive characteristics not yet applied. It has become even clearer that employing characteristics such as proximity, envelopment and spatialisation techniques (such as movement) within an un-amplified performance space, does increase perceived immersivity, but adversely impacts sound and visual processing. The continuing challenge of this research study is to find solutions to such issues with the aim of bringing all five immersive parameters listed in chapter 7 together in a cohesive and seamless manner. Some key points have been listed below which reflect the outcomes of this project against the research questions and literature review. Recommendations are provided that need considering for future projects which will further inform which immersive characteristics are relevant in music performance, and how they can be employed effectively in practice.

- **Movement**: It is evident that the physical movement of musicians in the performance enhanced immersivity as an interesting auditory experience, likely due to the spatialisation of sound sources. This is a key characteristic of spatial and immersive music which requires further investigation, and should include not only the movement of musicians but also virtual sound-sources. It is also worth investigating how movement can be applied to the audience, by allowing the audience to freely explore the performance space.

- **Sound Processing:** The absence of a sound reproduction system has potentially impacted sonic clarity and balance, as this may have provided further control of audio sources in a given space. In the case of this project, negative outcomes were directly linked to the distance between instruments and audience members. As the strings are the least dynamic with regard to natural amplitude levels, a larger ensemble may have been necessary. Nonetheless, both projects thus far, indicate that greater care is needed to create a robust sound stage for all listening positions in performance spaces regardless of size, which may need some form of amplification for greater sonic intelligibility. It is clear that sound reproduction systems need to be considered going forward, which will not only

be beneficial for sound processing, but also for spatialisation techniques and envelopment.

- **Envelopment:** Envelopment seems to have been sufficiently executed through this unique delivery format. The multi-directional projection of sound sources was perceived positively by the audience, further cementing its position as an integral characteristic in immersive music performance. Even without the use of loudspeakers, the presentation of performers in a space that breaks from the traditional front-back norm has presented audiences with a unique method to experience live music. There is certainly room to explore this characteristic further, in particular with the implementation of a loudspeaker array.

- **Visual Processing:** As with the quality of sound balance, visibility persists to be an issue in this study when using unusual delivery formats to explore proximity and envelopment. Although this project has produced better visual processing results than that of the experimental setups in project one, it is clear that visibility must be improved. The in-the-round and circular segmented formats (projects 1 & 2 respectively) demonstrated an interesting approach appreciated by audiences. The unique experience offered by experimental delivery formats have thus far outweighed the issues with sound and visual clarity. Nonetheless, the aim is to find solutions where problems occur. Therefore, this delivery format requires development, or a new approach is needed altogether.

- **Proximity:** This parameter has strengthened its position as a key aspect of immersivity in music performance. It is therefore, imperative that the intimacy and inclusivity it affords continues to play a vital role in future projects.

- **Audience engagement:** The surprise element was used with good effect to add to the audience's sense of immersion. There is scope for such a technique to be explored further as a method to enrich engagement. This approach is additionally interesting because it enhances the audience's sense of envelopment and sound processing by naturally localising its position within the space. This is a technique used well in immersive theatre, where narrative freedom heightens the sense of anticipation. It is clear that audience

engagement is not directly rooted in verbal communication between the audience and performers. A deviation from the traditional front-back format, closeness to performers, simple but effective compositions, and the application of surround sound features are all contributing factors. This corroborates what had been hypothesised in chapter 7, that this parameter is much broader in definition than the other listed immersive characteristics. Audience participation has been recommended by participants in both projects thus far as a potential parameter to increase immersivity which requires serious consideration going forward.

Questionnaire – Approaches to encourage participants to complete the questionnaire in a timely manner have generated better response times that the previous project. This study will pursuit the primary goal to gather participant responses as soon after the completion of the event as possible.

This project has thus far corroborated what the literature review has already emphasised, in that proximity, envelopment and audience engagement play a pivotal role in the development of immersivity in music performance. However, this has not been directly linked by previous literature in the way that this study has revealed. Furthermore, the two projects discussed verify the significance of sound and visual processing in almost all performance paradigms, aligned with what previous research has underscored. But this evidence demonstrates that it is even more crucial and simultaneously problematic in immersive music performance. Thus, the outcomes of this project have validated previous research, but have additionally provided findings which require further exploration. Therefore, it has facilitated the collection of relevant information against all three research questions - it has improved understanding of immersive characteristics (RQ1), whilst shedding light on how immersivity in music performance can be applied successfully in practice (RQ2), trough participant responses (RQ3).

This project could be effectively deployed in any small to medium sized hall, however, two recommendation should be made for greater results. The first is to use a tiered seating plan for better visibility of all sound sources. The second would be to increase the size of the string ensemble to eight (double the quartet), so that the string ensemble's dynamics can match

those of the piano and drums. It is also recommended that all rehearsals should take place in the performance space in the same delivery format as the event itself.

11. Project 3: 'ELO-CREEK'

11.1 - Aim

This chapter outlines the third and final projects aims and methodology in employing immersive characteristics in a music performance. Its investigative aims reflect the outcomes from the previous projects, as well as consider any remaining factors that need to be examined against the research questions and the literature review.

Project three had been designed to further the understanding of this research on which elements enhance the immersive nature of a music performance. Both initial projects identified proximity and envelopment as key immersive characteristics, whilst the movement and surprise moments employed in project two were received positively, enhancing audience engagement. However, both projects also highlighted the fragility of an immersive environment with regard to the two most important factors in any live music event. Those are sound and visual processing i.e., the ability to hear and see sound sources with clarity. Both those characteristics are incredibly important, because as we have discussed (chapters 3 & 7), they permit the audience to assign visual and auditory meaning to what they are experiencing. The first two projects acknowledged that immersive arrangements such as the 'in-the-round' of project one, and the 'segments' format employed in project two, provided unique aural experiences, but in doing so, sacrificed sound and visual processing.

To explain this further, let's review an example from project one. When an audience member is close to a particular musician and their instrument (as in the 'in-the-round' performance), proximity was greatly enhanced, improving intimacy. However, this also meant that an increase in that musician's instrument volume against other instruments (next to the drummer for example), reduced the overall quality of sound balance for that individual.

Additionally, the 'in-the-round' and 'triangles' delivery formats produced greater envelopment on the horizontal plane with sound sources emanating from different positions in the space. The particular seating position of an audience member however, meant that

they could potentially not see some of the performers, or had to work harder to assign musical meaning by constantly turning to observe the physical action which made that sound. This was also true to some effect by the 'segments' layout of project two.

Taking all this into account, the aim of project three was to deliver a performance that did not suffer from the reduction of sound and visual processing when proximity and envelopment were increased. Another developmental point considered, was that both previous projects did not use a PA and monitoring system, which reduced the ability to control sound balance in the performance space. It was therefore pertinent at this stage of the research to explore the immersive and problem-solving possibilities offered by a large loudspeaker array. Finally, many of the design points discussed, should act as mediums for indirect audience engagement. However, some additional ideas had been developed to directly engage the audience in the musical material - thus, covering all five immersive characteristics outlined by the taxonomy.

10.2 - Methodology

Phase 1: Composing

A. **Immersivity**:

The aim was to combine proximity, envelopment with sound and visual processing seamlessly, without any of those parameters being affected negatively. A project that utilised an octaphonic loudspeaker system with a single performer at the centre of the space, whilst using compositional elements to engage the audience in a unique manner was chosen. This project attempted to realise the list of immersive characteristics listed in chapter 7 by:

Proximity – ensuring the width of the octaphonic array was not too wide, with the arrangement designed for a small audience.
Envelopment – producing surround sound on the horizontal plane through an octaphonic circular array.

Sound Processing – the octaphonic array should allow plenty of separation of the compositional material to create sonic clarity and employ spatialisation techniques.
Visual Processing – a single performer in the centre of the room should be visible from all listening positions, adding greater depth to the theory behind gesture and source bonding.
Audience engagement – using TouchOSC on iPads as a MIDI controllers, to allow audience members to control the position of some select compositional material within the room. The unique use of the space as a performance event, the octaphonic array and visual presence of the centred performer and haptic controllers, should also enrich audience engagement.

B. **Music**:

A musical style which focused on electronic elements, predominantly using synthesisers with some use of samples and sample-based instruments, was chosen for three reasons. First, it appropriately reflected the electroacoustic nature of the octaphonic system where the music can be specifically written and produced for loudspeaker reproduction. Second, as synthesized sounds, samples and sample-based instruments go hand-in-hand with computer generated music, a single performer would suffice, who could be centred within the performance environment to enhance visual presence. The third and final reason was to use MIDI controllers as performing instruments that are clearly visible with plenty of visual cues, thus improving visual processing (gesture) in a performance paradigm (laptop music) that is, to some extent, arguably devoid of it. The musical material was composed using simple repetitive melodic and rhythmic phrases as structures, in additional to popular production techniques that reflect computer-generated music, with the aim to create material that can be perceived as broadly palatable and engaging for general music consumption – aligned with this study's methodological intentions outlined in chapter 8.

Five compositions were written for the project and performed live in the following order:

1. Intro
2. Solar
3. Kings
4. Bi®∂Sun
5. T-Machina+

Each piece contains spatial characteristics that take advantage of the octaphonic system using various approaches that include:

- Focused static sounds in single speakers (great for separation).
- Focused static sounds in speaker pairs or room segments (see figure 10.4 for segments).
- Centred sounds – usually drums, bass and piano, or other important compositional elements for a larger encompassing sound.
- Spatialisation techniques - moving sounds to create spatial features
    - Rotating in a circular motion clockwise and/or anticlockwise
    - Moving from left to right or vice-versa
    - Moving from front to back or vice-versa

The key compositional ideas were formed in the studio, such as melody, harmony and rhythm, with some ideas on structure and arrangement. However, these were fully formed in the actual performance space using the octaphonic area, where appropriate judgements could be made on the effectiveness of the musical material within that space. This is particularly relevant when making decisions on levels, panning and any spatialisation techniques employed.

Phase 2: Planning & Delivery

C. **Performance Space**:

The nature of the work would be appropriate for any small to medium sized hall (low to minimum reverberance), with a relatively small octaphonic system radius to ensure fidelity in sound source proximity and localisation (not effected greatly by the room ambience). This system can be easily deployed in any relevant space as long as an 8-speaker array with matching speakers is available. Wherever there is a possibility for the material to be performed in different spaces, the size and shape of the room, as well as the power of the speaker system should be considered when making final decisions on the position and radius of the octaphonic system.

Figure 10.1 shows the setup during first trials. Figure 10.2 shows the same setup but with baffles between each speaker, to reduce reverberation, and increase visual focus for the audience. Dimmed peripheral lighting and spotlights were used to provide visual focus on the performers centre position and controllers (figure 10.3).

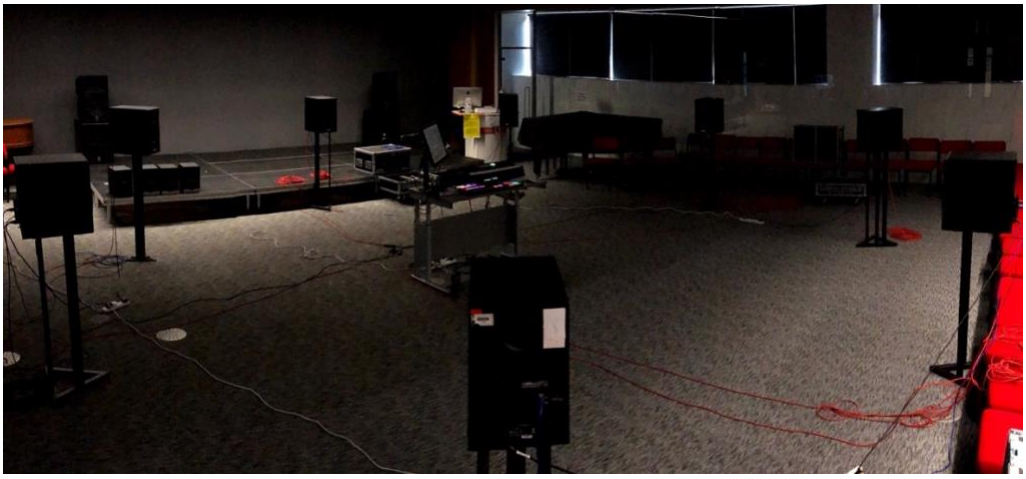


Figure 10.1 – Test trials

Figure 10.2 – Test Trials with Baffles

Figure 10.3 – Performance Control Station

D. **Delivery Format**:

The octaphonic system was arranged in a circular manner with speakers at 45˚ from each other, starting with speaker 1 directly in front (**F**) of the performer and speaker 5 directly behind (**B**), with a radius of 3.5 meters (figure 10.4). Previous research has demonstrated that

the octaphonic system provides a reliable image with good localisation cues, in particular when the minimum 60˚ angle for a reliable stereo image is exceeded to 45˚ [Bates, 2009, p.70].

Additionally, this system delivered envelopment on the horizontal plane by surrounding the audience. This radius was chosen to suit the performance space it was planned for, centred within the hall with as much distance form adjacent walls. The musician was placed in the centre of the performance space, as the optimum visible position to increase vantage points. The centre position can be described as the 'sweet-spot' where the performer has greater control of the surround sound image. The computer monitor and MIDI controllers were laid flat on a high table to optimise their visibility. As an added layer of interest, audience members were allowed and encouraged to explore the space freely, and to experience the performance (and therefore the soundfield) from different perspectives. The floor was segmented and labelled so that participants were aware of how they perceived the performance form different positions.

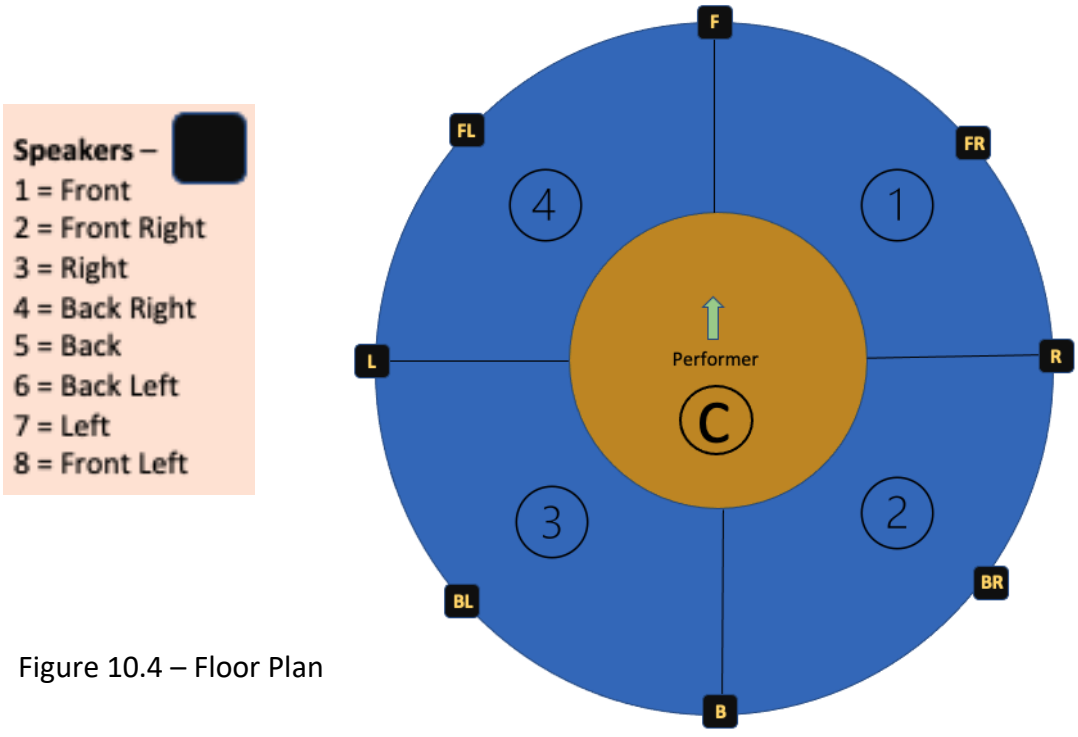


Figure 10.4 – Floor Plan

Maschine Mk3 & Maschine Jam by Native Instruments (figures 10.5 & 10.6 respectively) were used as the core performance instruments. These were specifically chosen as performance tools due to their visually engaging characteristics, which use backlit MIDI controls with multiple colours. In addition, their haptic nature, which includes, pads, pods, screens and

ribbon plates, makes them an advantageous instrument when attempting to improve musical gesture in computer-generated music performance.

Figure 10.5 – Maschine Mk3

Figure 10.6 – Maschine Jam

Using the Maschine software application (as an insert plugin), the projects mixer (figure 10.7), was routed externally into Ableton Live. The output monitoring of Ableton Live was setup as four stereo pairs which bypass the master output, allowing individual tracks to be routed directly to any speaker pair (figure 10.8), which correspond to the 8-speakers in figure 10.4, beginning with the Front (**F**) speaker as number 1, Front Right (**FR**) as speaker 2 and so on.

Using Ableton's Surround Sound Panner plugin (figure 10.9), the performer could then place sound sources anywhere within the 360˚ horizontal plane using phantom imaging. In addition, MIDI controls could be either automated or performed in real-time to control the position of a sound source within that space with great accuracy. The plugin uses *X & Y* dials to place the sound source in the desired position within the horizontal soundfield. The *Focus* dial provides greater emphasis of that sounds position within the array, where the shaded circular area increases or decreases in diameter depending on the level of focus – this was an effective tool for making sounds emanate from very defined positions if desired, or vice-versa. The *Rotation* dial which rotates continuously without stopping (a unique feature for a dial), allowed for the position of a sound source to be rotated fully on the 360˚ plane – this was particularly useful when automating or controlling a sound sources position in real-time.

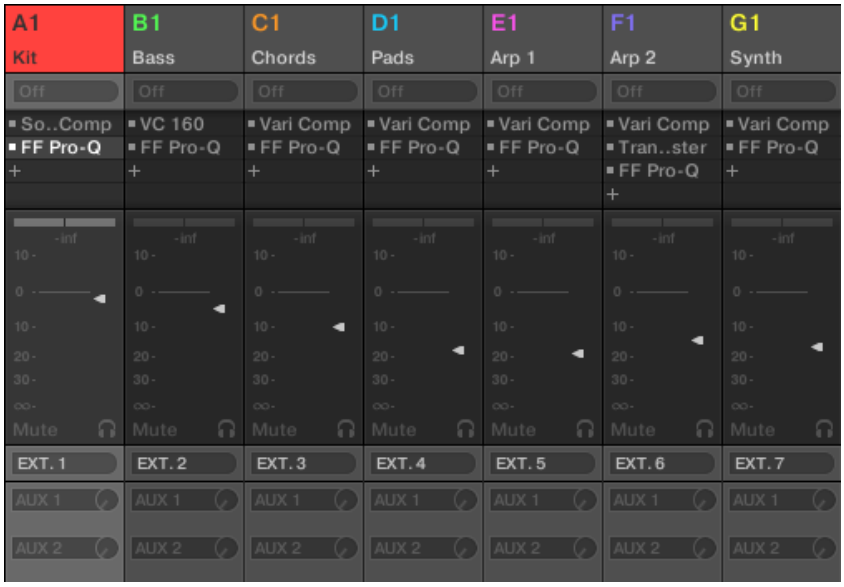


Figure 10.7 – Maschine software mixer

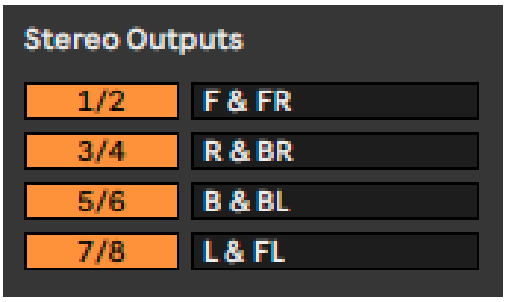


Figure 10.8 – Ableton output configuration

Figure 10.9 – Ableton Surround Panner

Finally, the TouchOSC application was used as a touchscreen MIDI device, where the position of an individual sound could be manipulated with the touch of a finger using iPads. Specific

templates had been programmed by the author, in which the X & Y Axis of the Surround Sound Panner (figure 10.9) corresponded to the X & Y Axis of TouchOSC (figure 10.10). These were setup using Ableton's MIDI assign feature. Two iPads were made available to the audience in which they were able to control the position of selected sounds within the performance. These were usually ambient elements with minor melodic and rhythmic importance to ensure the integrity of the musical material was not jeopardised. More devices however could be made available, and so it is down to the composer's preference on how much musical material the make available to the audience to interact with.

Note: due to Covid restrictions during the time of the event, we were not permitted to use the iPads in the performance.

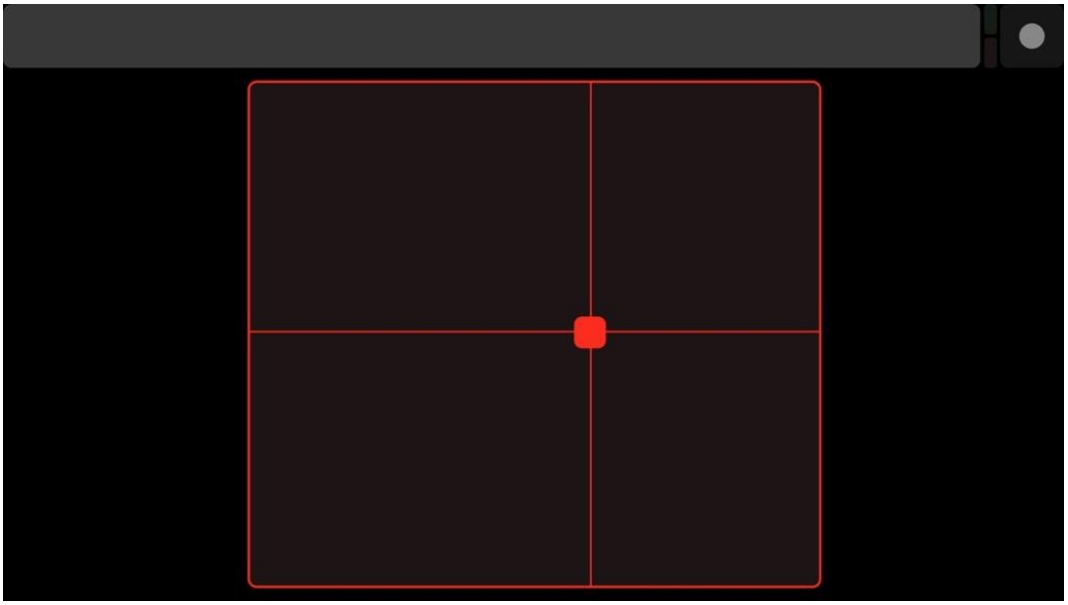


Figure 10.10 – TouchOSC

Phase 3: Capture Evidence

E. **Capture AV**:

An Ambeo microphone was placed in the centre position above the performer to capture the room's soundfield. A GoPro in an elevated position (attached to the Ambeo mic stand), provided a birds-eye view of the performer's setup (figure 10.11). A second GoPro was placed next to the MIDI controllers for a close-up of the performer. The processed binaural stereo file from the Ambeo recordings was then edited along with the GoPro footage. Videos of each track are available at the following links:

1. Intro
2. Solar
3. Dance with the king
4. Bi®∂Sun
5. T-Machina+

Figure 10.11 – Soundfield Mic position

F. **Questionnaire**:

The survey uses a variety of qualitative and quantitative questions, with the aim of collecting a variety of reliable responses against the immersive parameters employed. Some questions are open to allow participants to provide their personal opinion, whilst some are closed where participants answer against a scored matrix.

The questions were as follows:

1. What most engaged you about the performance?
2. What was less engaging about the performance?
    - *Two open questions to receive general responses from participants that identify positive and negative elements from their perspective.*
3. Was there a position in the room in which you **could** hear the music clearly? *Mark the table.*

4. Was there a position in the room where you could **not** hear the music clearly? *Mark the table.*
    - *Responders are able to choose from the five segments exhibited in Figure 10.4. The table will help this project identify the most and least effective listening positions within the performance space. It would also identity whether the surround sound image remained stable across the entire listening space.*
5. Did you feel enveloped (surrounded) by the multi-speaker sound system?
    - *The scored system will ascertain the effectiveness of the music performed through the octaphonic system as an immersive arrangement.*
6. How engaging was the movement of sound in the space?
    - *The scored system will ascertain the effectiveness of musical elements moving within the performance space as spatial characteristics, whilst also indicating the strength of the phantom images as localisation cues.*
7. Did your ability to explore the space contribute to your enjoyment of the performance?
    - *The scored system will ascertain the effectiveness of being able to explore the performance space through various vantage points.*
8. Did your proximity to the performer enhance your engagement to the music? Why?
    - *The first part to this question will ascertain whether proximity was achieved. The second part of the question will collect subjective responses from participants perspective, in search of whether the proximity enhances engagement through visual processing such as gesture and agency.*
9. How immersive did you find the concert?
    - *The scored system will ascertain the overall effectiveness of the immersive parameters employed in the performance. This has been used in every project questionnaire to provide some continuity against this studies key questions on immersivity.*
10. What could have made the concert more immersive?
    - *Also used in every questionnaire, this is a valuable question in collecting subjective opinions on the subject of immersivity. Its importance lies in the audience's perspective on what immersivity is, which is central to this studies key research aim.*

The questionnaire was formulated using Google Forms and made available to participants before the performance via email. This is preceded by the following statement to provide context to participants on the performance characteristics, and how we may consider 'immersivity' in music performance.

> *'Today's concert consists of a single performer using electronic music equipment, projecting the sound through a circular 8-speaker array, with the performer at the centre. The aim of this project is to explore techniques that may contribute to 'immersivity' within live music performance.*
>
> *Immersivity in music performance does not have a clear definition, but we can think of it as the listeners proximity to performers and loud-speakers, and how the sound surrounds them. It is also worth considering the audio-visual aspects of the performance along with any other engaging factors.*
>
> *Responses to this questionnaire are recorded anonymously.'*

This was clarified in person on the day of the event, whilst participants were encouraged to complete the questionnaire at their earliest possible convenience to minimise any lapses in memory, before and after the event, in addition to a follow up email on the same day.

Phase 4**: **Synthesis & Conclusions

G. **Collect & Collate:**

The table below summarises participant responses from the questionnaire. 22 participants responded from a possible 24. All participants responded within the same day, other than 2 who responded with 24 hours. Gender was proportionally represented (13 male, 11 female). Ages ranged from early 20s to late 60s.

Audience Questionnaire	
17. What most engaged you about the performance?	Responses were overall very positive, with many participants indicating that the performance was a fairly unique experience for them. The most engaging aspect was that participants were able to explore the space freely from different perspectives. This was followed by the engaging movement of sound in a surround sound space. Other aspects highlighted as being particularly engaging included, the intimate environment; the ability to see the performer and equipment being used in real-time; and the quality of sound clarity and musical content.
18. What was less engaging about the performance?	Approximately half of participants did not highlight anything that lacked engaging characteristics. A few participants indicated the possible awkwardness of being able to explore the space freely, and not knowing how to do this with other people in the space. Another element was the lack of lighting being used to enhance the musical material. Finally, 2 participants would have preferred a variety of musical styles rather than one focused genre.
19. Was there a position in the room in which you could hear the music clearly?	Most participants indicated that the music was clearly audible in all segments, with all but 1 participant indicating the centre position as the most clearly audible. A small number of participants indicated a range of segments as clearly audible, but this did not highlight any consistencies.
20. Was there a position in the room where you could not hear the music clearly?	All but a few participants indicated that there was no position in which the music was not clearly audible. However, segments 2 and 3 were selected twice each and segment 1 once. This indicates a solid and consistent dispersion of sound across the space.
21. Did you feel enveloped (surrounded) by the multi-speaker sound system?	Average rating out of 5 = **4.7**
22. How engaging was the movement of sound in the space?	Average rating out of 5 = **4.6**
23. Did your ability to explore the space contribute to your enjoyment of the performance?	Average rating out of 5 = **4.4**

24. Did your proximity to the performer enhance your engagement to the music?	Average rating out of 5 = **4.4**
25. In your own words, please explain why your proximity to the performer, negatively or positively, contributed to your enjoyment of the performance?	Participants overwhelmingly highlighted that their ability to see the music being performed in real-time, whilst making connections between the performance articulations and sounds, made the overall experience far more interesting and engaging. Participants also highlighted the proximity to the performer as something unique not normally witnessed in such events. Some commented that this style of performance made them feel less of a spectator and more as part of the performance, with some participants using the terms '*more immersive'* and '*shared experience'* to express their thoughts. Finally, the lighting emanating from the equipment added to the overall enjoyment.
26. How immersive did you find the concert?	Average rating out of 5 = **4.6**
27. What could have made the concert more immersive?	Participants overwhelmingly highlighted lighting as an element that could have enhanced the musical content, not only to highlight specific compositional elements, but to also dim the lighting at times to heighten musical focus. A more engaging space that better accommodated and enhanced the musical experienced was mentioned by several participants. Other notable comments include, audience participation, visuals and being less aware of the space and sound sources.

H. **Summary**:

Space, Proximity & Visual Processing: The space was adjusted effectively to create an intimate performance environment which audience members could easily explore, providing good proximity to both the performer and sound sources. The number of audience members could have been slightly higher to give the performance the feel of an event, however, due to Covid restrictions this was not possible (limited to 8 participants for each of the 3 performances) – ideally 16 would have been more appropriate. Participants overwhelmingly highlighted that the proximity to the performer with the ability to visualise and therefore process the sound heard against the physical gestures made in real-time, enhanced their

experience. This was expressed in qualitative responses and supported by the 4.4 quantitative rating it received.

The arrangement of the space was conducive to the visual and sound processing specifically promoted in this project, providing focus to the central performer and making gesture clearly visible. The engaging haptic electronic equipment used, enhanced gestural cues, enabling the physical actions to be effectively assigned to musical meaning. The audience's lack of experience and knowledge with such performance hardware, or how gestures can be minute and less theatrical in relation to their musical outcome, did not seem to diminish their overall experience. However, it may be that participants would not identify this unless it was explicitly pointed out.

Some respondents did highlight that the space did not feel like a real performance space, underscoring the event as a research project taking place in a university space. A few participants also highlighted that the ability to move freely was a new performance model which felt unusual, acknowledging that participants may have felt awkward and self-conscious. It is possible that audiences could become more accustomed to this performance paradigm if it was used more widely. Most participants suggested the use of lighting and visuals to enhance the musical material. In some cases, it was also suggested that less lighting would have further engaged listeners in the material, making them less aware of the space. Additionally, it was pertinent of one participant to suggest that not being aware of the sound sources (the loudspeakers) would have enhanced the immersive characteristics.

Sonic Clarity & Audio Processing: Due to the setup of the performer and sound sources, the floor was segmented so that audience members could decipher where the overall sound image was at its best and worst within the listening space. An uneven dispersion of sound across the performance space was possible, as it was designed from the perspective of the central position where the performer is situated. Participant responses did not acknowledge any issues, meaning that the overall sonic image, sound separation and spatialisation techniques remained robust across the listening space. However, it was also evident from testing and participant responses, that the sound image was indeed strongest in the central position.

Envelopment & Spatialisation: Both techniques received a high score from participants (4.7 and 4.6 respectively), meaning that the octaphonic system and the movement of sound in the space positively contributed to the overall experience, and therefore the development of an immersive environment. The octaphonic system had been employed effectively to surround the listener and create audio separation and spatialisation of the compositional material. This was particularly important in pieces that entailed complex textures such as *Bi®∂Sun*.

Spatial features in which melodic and rhythmic elements moved within the soundfield provided extra compositional depth and interest. These elements were handled with care, ensuring that the overall sound image was not jeopardised when specific sounds incorporated spatial cues. The 8-speaker array ensured that localisation accuracy was robust across the horizontal plane and used creatively within each composition. This was accomplished by a cohesive management of panning and the overall soundfield image across the entire performance without major differences between pieces. This principle was supported by participant responses.

The system provided a good level of envelopment on the horizontal plane which delivered the material with power without being overwhelming. However, some respondents commented on wanting less bass even though a sub-woofer was not used (which would be the norm in the traditional sense, i.e. an 8.1 system). The author was impressed at how complex dynamic and textural material can be controlled with great accuracy through an octaphonic system of this kind, which broadened the creative opportunities afforded to the composer and performer.

Audience Movement: The ability to move within the space provided audience members with the possibility of experiencing the space and music from different vantage points. Participants indicated this as one of the most engaging aspects of the performance, delivering a unique experience which is unusual for music performance events. A potential consequence of one segment providing a better sonic image than others, is that audience members could potentially compete for that space (as seen in traditional setups, where 'front & centre' is usually favoured), but this was not the case here, due to the strength of the sonic image across

the entire listening space - strengthened by the author's ability to develop the musical material and its delivery in the actual performance space. Participant's capacity to explore the space received a positive quantitative score of 4.4.

Audience Engagement: Participants gave the overall sense of immersion of the event a 4.6 rating, which indicates a very positive perception of the techniques employed. Overall audience engagement was enriched by the use of the space, the arrangement of the performer and sound sources, and the ability to explore vantage points. This setup produced positive responses against this delivery model, such as "*more immersive"* and making members feel that the performance was a "*shared experience"*. The techniques mentioned however were implied rather than explicit practices to enhance engagement.

I. **Outcomes:**

The project was successful in delivering its intended immersive characteristics through various parameters as supported by participant responses, highlighting the progress made in each consecutive project. By this stage of this study, the taxonomy of immersive characteristics had been established, therefore it is appropriate to review each parameter individually. As expected, questions have arisen which demonstrate the need to further explore all five immersive parameters collectively and independently.

Proximity – This parameter was effectively used to engage the audience with the performer's physical actions and distance from sound sources. This was accomplished by the intimate size of the performance space, and the ability for audience members to explore vantage points in relation to the performer and sound sources. Proximity has established itself as a significant immersive characteristic but it may require a deeper understanding of its role. For example, is it possible to produce more quantifiable data from further studies to deduce its relative importance in a given space? We could assume that the intimacy offered by this project would diminish if the space was augmented, therefore, could different spatial arrangements be examined to determine the point at which intimacy is decreased?

Envelopment – The octaphonic array was very effective in enveloping the listener on the horizontal plane, but further progress could be made by exploring projected sound on the vertical plane. It would be useful to investigate the outcomes of a system which reduces or eliminates the audience's awareness of sound sources altogether. Further research could be undertaken on how the size and arrangement of the space as well as the volume of the material can positively or negatively contribute to envelopment.

Sound Processing – The arrangement of the musical material to take advantage of the multi-speaker array was effective in creating timbral and textural separation for greater sonic clarity as well as provide spatialisation cues for a unique listening experience. This project purposely employed a conservative use of spatialisation techniques by remaining cautious in its application as to not distract from the overall musical experience. However, there is certainly room to further explore spatialisation techniques and challenge listener expectations, particularly where physical and virtual sound sources are used in conjunction.

Visual Processing – The project was successful in highlighting the significance of physical actions in music performance, specifically for the delivery of computer-generated music in real-time. It is clear however that audiences expect more, especially with regard to lighting and visuals to accompany the musical material, which is common practice in commercial settings. This may now be considered an intrinsic component of the live sound experience from the audience's perspective, rather than as an additional layer. Further considerations can be made to investigate how visuals which enhance the musical content, can play a crucial role in the development of immersivity in music performance.

Audience Engagement – The project lacked overt methods to engage the audience in the performance with the ones planed (TouchOSC) removed for safety reasons. The absence of direct methods to engage the audience with the material did not seem to diminish their overall enjoyment. It is evident however that participants desire to engaged with the musical content. This can be accomplished directly or indirectly, or at least, lead them to engage with the material directly in their own capacity, free from judgement. The informal delivery format employed, uninhibited from static listening positions, established an inclusive environment which participants clearly appreciated, but some may have found daunting. This parameter is

extremely difficult to measure due to its subjective qualities when we consider how differently individuals engage with any day-to-day activities. Consequently, this parameter requires further research on the significance of direct and indirect methods of engagement.

The planned component to directly engage the audience with the musical material by using tablets with TouchOSC, would have allowed participants to control and move selected sounds within the performance space. Unfortunately, this element was removed due to Covid restrictions. It is therefore difficult to interpret whether this method would have yielded some positive responses. It may have been an innovative addition to the performance, but it may also have acted as an added quirk, rather than an integral feature. This technology affords the creator greater scope of explore immersive sound projection, especially for installation works where audience members could engage directly with the space by actively taking part in the musical experience. Any such designs would necessitate a compositional approach that considers this technology as a primary feature within the work, rather than secondary.

Questionnaire – Efforts to encourage participants to complete the questionnaire as quickly as possible generated a fast response. Receiving responses from the majority of participants on the same day as the event is very positive. The ideal situation would be to devise a system that enabled participants to complete the questionnaire immediately after the concert.

This project has provided a better understanding the various parameters surrounding immersivity in music performance and their application in practice. As with the previous projects, responses have demonstrated that proximity creates an intimate environment which is additionally engaging from the consumers perspective. This supports theories from the literature review, but extends understanding by suggesting that this characteristic can exist even when audiences are given the freedom to explore the listening space, and thus control their distance from sounding sources and performers. The proposition of envelopment as a key immersive characteristic is further supported here by utilising a traditional octaphonic system in an electroacoustic performance medium. This project supports theories by other composers that loudspeaker arrays provide greater musical separation and intelligibility of spatialisation techniques. The octaphonic array also corroborates that the integrity of the sonic image is more robust when using a larger

loudspeaker system. Additionally, the unique arrangement of a performer in the central position, supports our understanding of physical action as an integral aspect of music cognition. What this project explores successfully, is that audience processing of musical meaning can remain strong, even when there is limited knowledge of the instruments and applications used as long as the physical actions that create the sounds are clearly visible. This is an interesting topic that requires further exploration to determine whether processing of physical action is as coherent when using computer music controllers as that of traditional instruments. This suitably transitions into audience engagement, where the visibility of the performer using computer equipment, along with the arrangement of the space, the unique speaker system for a contemporary music performance and the surround sound image, all contribute to indirect audience engagement. The strength of the sound and visual processing in this project in addition to the performer's interactions with the audience, affirm that knowledge is a positive contributor to audience perception even when the material is a new listening experience. This project and this study thus far, supports the authors theory that musical material designed as broadly accessible for the general consumer performs a critical role in enhancing audience perception.

This project has been instrumental in shaping the taxonomy listed in chapter 7 by effectively investigating research question one through the appropriate application of research questions two and three. As with the previous projects, the potential for this work to be deployed in other performances spaces is positive. The main requirement is an octaphonic loudspeaker array at a minimum, constructed in a similar circular format. However, larger systems and different specifications with regard to speaker placement are not problematic as long as the performer is able to make appropriate adjustments in the space prior to the event. This project is a suitable example of how non-traditional delivery formats could be deployed in performances spaces effectively, with just the need for an appropriate surround sound system, at least on the horizontal place. The single performer aspect is a great advantage in minimising the amount of space required whilst maximising the area in which the audience is able to explore. The author agrees with participant responses that a professional event space would be advantageous for this kind of project, especially when the musical work is enhanced by lights and visuals.

Section D

Conclusions

12. Conclusions

This chapter summarises to which extent this study has realised the aims outlined in chapter one through the use of primary and secondary research. It considers the impact of the investigative outcomes against the research questions, highlighting what has been learnt along with what has been contributed toward the gaps in knowledge and practice outlined. Theories obtained from previous literature are reviewed against the outcomes to determine which aspects are corroborated and which are contradicted. Finally, this chapter acknowledges areas which require further investigation.

The key research aim reflected by research question one was to attempt to define the concept of immersivity in music performance due to an absence of such definition established by previous practice and literature. The taxonomy of immersive characteristics in chapter 7 provides a comprehensive and practical organisation of parameters to be considered. This list offers a substantial degree of definition for a performance medium that had not been explained previously in as much detail and with as much clarity as it has in this thesis. As such, the taxonomy delivers a useable categorisation of immersivity for creative practitioners, who can consider the various indicative compositional and spatial attributes delineated within their own work. This outcome provides the key contribution to knowledge offered by this study. The hybrid research method employed, which blends practice-based and practice-led approaches with traditional qualitative and quantitative data collection procedures, was fundamental to realising the research aim.

The literature review which enabled potential theories to be extracted is supported by the primary research conducted through original projects. Audience participation played a significant role in validating or challenging these theories, ultimately, helping to shape final outcomes. The important function of audience perception could not be downplayed, affording this study a greater level of objectivity by reducing the researcher's potential for speculative evaluation - a gap in practice this paper endeavoured to explore from the outset. Although the use of participants in research for the creative arts has become more common, the theories surrounding this particular field (immersive music performance) has lacked such

methodological approaches - as detailed in the literature review. The rigour of this approach is highly recommended, and is one that will continue to play a valuable role for any future research by the author in this field.

It is difficult to measure the success of employing popular music compositional techniques with the purpose to produce accessible music for a wider demographic. This methodology was born from an initial observation made from the literature review which highlighted the substantially experimental music approaches employed by previous notable expects. Furthermore, the author's own compositional expertise in popular and contemporary music formats, meant that the created music needed to play to the author's strengths. The author's original motivations for embarking on this study was to develop music projects with an audience-centred approach, because it was evident from personal experience that this method enhanced audience engagement with the performed material. For those numerous reasons I attempted to produce musical material that largely appealed to its participants whilst still appropriately investigating immersivity - this is also a gap in practice acknowledged in the literature review. Results from participant questionnaires demonstrate that engagement and general audience enjoyment was perceived highly. This approach was not assumed for the purpose of recording data on the quality of the performed material, but rather, to ensure that the music did not unintentionally depart from the key investigative aims due to needless complexity. It does not mean however, that a different approach may have yielded different or indeed negative outcomes; but it is an approach that seemed logical from the author's perspective. As the aim of this research was to explore methods in which immersivity can create unique and innovative experiences for the audience, it is a highly recommended approach for developing compositional material for this purpose, and will play a central role in the author's future research.

As the taxonomy is central to this paper's research aim, it is fitting that the following conclusions are disseminated through each listed parameter. These consider what specifics are corroborated and contradicted from the literature review, whilst making recommendations creators should deliberate when designing an immersive music project. As such, it clarifies the outcomes from research questions two and three, before providing suggestions for future investigations.

Proximity

- Proximity enhances intimacy by reducing the distance between performers and sound sources.
- The physical presence of musicians engages the audience on a personal level which can develop inclusivity and emotional connection. In some cases, a level of equality between the musicians and audience had been expressed.
- Closeness can help to increase the bond between the visual and aural elements by delivering focused visual features which enhance performative characteristics such as timbre, musical expression, physical action and emotional communication.
- It is highly recommended that proximity is considered for an effective immersive music project where creators sensibly consider the suitability of the delivery format within any given performance space.
- These points corroborate much of what previous literature had theorised, but this study provides further insight to establish proximity as a key immersive characteristic within music performance practice.
- The extent to which proximity yields a positive experience can be further explored. Future investigations may wish to consider how spatial characteristics such as variations in delivery format, distance from sound sources and visual clarity are central to its success.

Envelopment

- The projection of an enveloping sound-scene produces similar qualities to how listeners hear any given soundfield, including spatial characteristics such as movement and localisation. Therefore, envelopment is a key immersive characteristic due to its capacity to encourage the cognition of three-dimensional sound which is an innate quality of human hearing.
- Surround sound projection which includes all sound-points such as speakers and musicians, provide the listener with a distinctive perspective of how to experience music performance by diverging from the traditional front-back model.

- Surround sound projection can provide additional sonic clarity to complex musical material due to the human ears ability to process the location and movement of sound points with great accuracy within a soundfield.
- The positional arrangement of sound sources, compositional detail and performance accuracy of enveloping sound-systems will determine the level of success in which immersivity has been experienced.
- Previous research on listening, with particular attention to localisation and spatialisation from both physical and virtual sound sources, have been validated. It should be noted that this study did not attempt to further understanding of this particular parameter, but to employ what was already known in a manner that was effective in immersive music practice.
- As such, the use of spatialisation techniques as well as surround sound systems with a minimum of eight identical speakers in a circular arrangement have been effectively deployed and were perceived positively by audiences.
- It is encouraged that the methods discussed in this thesis to enhance envelopment are genuinely considered for immersive music practice. The literature review in chapter 7 provides a detailed account on what must be contemplated and what should be avoided.
- There is scope to investigate how an enveloping sound space is perceived if sound sources are not visible, as well as the impact of vertical sound projection.
- The architectural characteristics of performance spaces and the distance between the listener and sound sources are likely to colour the timbral characteristics of the music. Therefore, these are also in need of further exploration to determine their influence.

Sound Processing

- Sonic clarity precedes immersivity, where any intended immersive characteristic can only be truly experienced if the overall sonic clarity is consistent and intelligible throughout the listening space.
- It is recommended that due care is made when designing a project that employs a non-traditional arrangement of the audience and musicians to ensure that its effect on sound clarity and balance is mitigated using any methods possible.

- As room acoustics such as reverberation can significantly influence and colour the distribution of sound, the size and shape of a given performance space along with the delivery format must be carefully considered. Thus, creative decisions should be made with these in mind as well as considering the suitability of the musical material for that given space.
- Sound sources placed around a listening space take advantage of the human ears ability to localise sound-points which improve sound processing due to spatial separation.
- The larger the quantity of loudspeakers used, the greater the quality of the sound image, thereby increasing the size of the 'sweet-spot'.
- Providing the listener with musical material that possesses interesting spatial characteristics enables audiences to process the distributed sound in ways that potentially have not been experienced previously, thus enhancing immersivity in music performance.
- The potential offered for peripatetic vantage points in which audiences can experience the musical material from different locations (where possible), thus interacting with the performance space (as long as this is appropriate for the setting) should be considered.
- The primary research conducted in this study has demonstrated that sound processing is a significant element of immersive music practice, providing new information relevant to this field.
- As with envelopment, the outcomes corroborate previous knowledge with regard to human hearing and sound-source localisation within a given soundfield.
- Chapter 7 provides details on human hearing, localisation and spatialisation, the effect of space on musical material, and listener perception that can further inform prospective practice in light of these suggestions.
- Further study can identify the extent to which spatialisation techniques impact immersivity by investigating potential implications to which extend the movement of sound-points complement or distract from the musical material.
- Future investigative recommendations for envelopment are also relevant for this parameter, such as concealed sound sources, vertical sound projection and the influence of room acoustics.

Visual Processing

- As with sound processing, visual processing is a natural and cultural feature of human cognition, enabling individuals to make greater sense of their environment. Consequently, visual processing is inherently connected to music listening.
- This paper has proposed the term 'physical actions' for all relevant musical performance features, encompassing the performance of instruments, singing and any computer-based technologies such as MIDI controllers. The purpose of this is to simplify previous theories which had offered different terms for different human performance attributes.
- Physical actions are integral characteristics of the listener's ability to assign meaning to the sound they hear against what they observe. It is therefore recommended that all performers are clearly visible to all audience members. Where this is not entirely possible, mediated means are suggested.
- Knowledge of how the musical instruments or equipment employed function, do not appear to inhibit the listeners' ability to place meaning - i.e., where source-bonding doesn't naturally exist due to unfamiliar sounds.
- The importance of visual processing is relevant for both acoustic and electronic music.
- Visual clarity plays a pivotal role in fulfilling basic audience expectations before further immersive characteristics can be explored, particularly for music with live performers.
- The theories behind the importance of visual processing by previous papers, such as gesture and utterance are validated through this study.
- As with sound processing, this study argues for the increased significance of visual processing in music performance, particularly that which exhibits innovative delivery formats - something that had not been recognised by previous literature.
- Although this paper recommends the use of visual aids in music cognition, some practitioners may disagree. It has been theorised that the absence of sound-sources can enhance the listening experience by encouraging audiences to exclusively focus on the sound and music. However, this is likely to be style specific, where acousmatic and sound diffusion practice may require different approaches to immersive music. This contrasting notion provides potential for further investigation, where a simple experiment in which the same musical material, in the same space is performed with or without the clear

presence of sound-sources. This will be particularly enlightening where physical performers are heard within the space but hidden from view.

- Additionally, it is worth exploring if meditated means can supplement and enrich visual processing. This approach may also contribute to proximity where not all listening positions can be close to all sound-sources.
- Finally, the subject of lighting and visuals to enhance the musical material needs further study with the aim of investigating the degree to which it enhances the immersive experience. A simple experiment could compare an immersive project with or without creative visuals.

Audience Engagement

- The visual component of the performance and the space in which it is delivered are integral factors in the way the musical material is perceived, which supports the observable 'action-to-sound' theory.
- The musical material must engage the audience to the degree in which it meets the audience's predetermined subjective expectations.
- As such, expectations can range dramatically. The theories behind knowledge and risk (discussed in chapter 7.5) from the listener's perspective are validated by this thesis, which highly recommends an audience-centred approach in project design.
- Audience engagement has recorded high levels of success across all projects, which supports this paper's theory that proximity, envelopment and clear sound and visual processing indirectly contribute to audience engagement. This includes experimental approaches such as spatialisation techniques, in particular the movement of physical sound-sources, surprise moments, and the innovative use of space to create inclusive environments.
- Direct methods of engagement such as audience-performer interaction are recommended to enhance knowledge by ensuring that audiences have a greater understanding of the performance taking place. This is even more pertinent from an academic research standpoint to enhance the quality of participant responses. Verbal communication is therefore vital from a performance perspective, and also from a research stance when attempting to encourage faster response rates.

- Other direct methods of engagement such as performer-performer interaction, audience-audience interaction and audience with musical material interaction, have been considered but not fully explored. The TouchOSC method designed for project three was unfortunately withdrawn (due to Covid restrictions) but will certainly perform a role in future investigations. The objective is to explore whether the direct contribution of the audience shaping the musical material and/or performance can enhance immersivity.
- Similarly, other methods to record audience engagement should be explored, particularly GSR technologies which would suitably supplement traditional methodologies.
- Audience engagement is clearly a broad and complex parameter due to listener subjectivity which is shaped by their own personal experiences - therefore, it is unlikely that clear definitions can be deduced. However, this paper has provided a list of characteristics that should be genuinely considered in order to improve audience engagement in immersive music performance practice.
- More can be done to investigate and therefore identify with added clarity which approaches to immersive music practice can be attributed to direct and/or indirect audience engagement.

It is evident that many of the recommendations and theories discussed for each immersive characteristic interconnect with each other. This should be considered a positive outcome, which demonstrates that the concept of immersivity in music performance is complex, but simultaneously contains certain characteristics which are integral to its successful application in practice.

In conclusion, this chapter provides evidence that supports queries raised by the research questions in response to the key research aim. Furthermore, the taxonomy of immersive characteristics stipulated offers a significant contribution to knowledge in this field of research, and as such, provides useable information for the prospective immersive music practitioner. Much of this study corroborates previous theories with no clear evidence of contradictions. It has in fact, built upon former research and methods of practice, bridging many previous theories to provide clarity to a performance paradigm which previously lacked definition. Although these outcomes deliver strong foundations, there are many investigative

strands that require supplementary exploration which will ultimately strengthen the understanding and appreciation of immersivity in music performance.

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