Potts, Ben N.

Sound as, and beyond, sculpture :a creative investigation of physicality, space and movement through otoacoustic emissions

Sound as, and beyond, sculpture:

a creative investigation of physicality, space and movement through otoacoustic emissions

Ben Nigel Potts

A commentary accompanying the creative portfolio submitted to the University of Huddersfield in partial fulfilment of the requirements for the degree of Doctor of Philosophy

April 2017 (Amended September 2018)

Contents

Statement of Copyright

Please note: Elements of this thesis have been previously published (listed in Appendix A)

List of Portfolio Works and Materials

Provided on the accompanying memory stick

1. Touch Tactile 1a. Touch Tactile painting 1b. Touch Tactile sound	7. Static 7a. Static render 7b. (not)Static render 7c. Static patch 7d. READ ME
2. Cuboid 2a. Cuboid photograph 2b. Cuboid photograph 2c. Cuboid photograph 2d. Cuboid sound	8. Shift 8a. Shift sound 8b. Shift patch (stereo) 8c. Shift patch (4 channel) 8d. READ ME
3. Nothingness 3a. Nothingness photograph 3b. Nothingness sound	9. Seesaw 9a. Seesaw render 9b. Seesaw patch 9c. READ ME
4. __— 4a. __— photograph (Coventry University) 4b. __— sound	10. Grow 10a. Grow sound & video 10b. Grow patch 10c. READ ME
5. If; slowly 5a. If; Slowly photograph 5b. If; slowly sound 5c. If; slowly video trailer	11. Forms and Perspectives 11a. Forms and Perspectives render 11b. Forms and Perspectives patch (stereo) 11b. Forms and Perspectives patch (16 channel) 11c. READ ME

Acknowledgements

I would like to thank my supervisor, Michael Clarke, and co-supervisor, Monty Adkins, for their exceptional support and assistance during this project. I would also like to thank the members of staff that have taught and inspired me during both my undergraduate and doctorate degrees, the postgraduate and wider artistic community for their inspiration and excellent friendship, and Alder Davies for her help and support.

I would like to thank my friends and family who have supported me in many times of need; especially my mother, father and grandmother. This project is dedicated to them.

Table of Figures

Abstract

This research project has explored the relationship between sound and sculpture, looking particularly at how sound can become sculptural. A sound sculpture is defined in this project as a sound-only entity, which explicitly extends sound's physical and spatial aspects to take on the role of a physical, visual sculpture. In this research, this is achieved by the use of otoacoustic emissions. There is a lack of music and sound art material that actively intends to utilise the creative potential of otoacoustic emissions.

This portfolio of works explores the bodily sensation of otoacoustic emissions and importantly, the agency the audience/listener has on changing their own perception and experience of the sound through their movement choices around an installation space. This novel application of otoacoustic emissions is what the author terms 'otokinetic shaping'. This goes beyond that of the visual sculptural paradigm by introducing an element of audience participation and control. The pieces are created in a manner in which they are a collaboration between the artist and the audience, with the audience having more creative control than the artist on the work's sound, structure and duration.

The works also examine creative themes such as minimalism and indeterminacy controlled by computer algorithms as a method of extending the already limited decisions made in the creative and compositional process by the artist.

Introduction

This project originates from my antecedent love of abstract visual art. Since being a teenager attending art galleries, I have been fascinated with abstract paintings by Robert Motherwell, Jackson Pollock and Franz Kline. Over time, this passion also extended to minimalist sculpture. The works of Richard Serra, Dan Flavin, Robert Morris and Tony Smith, which use geometric forms, minimalist materials and ideas, were particularly influential. With a background and education in music and sound art, I have always had the desire to explore the practicalities of sound mirroring the same experience one might have when viewing one of these works; therefore, this project's objective was to explore forming relationships between sound and sculpture, particularly examining how sound could become sculptural and take on an equivalency of physical objects. Works from the beginning of the project investigate creating sound art using ideas behind the creation of visual art works, i.e. action painting and spatial sculpture. These works included the creation of visual art and sound art intended to be presented to the audience simultaneously, forming a multi-sensory installation conveying analogous abstract techniques.

After the first work, the relationship between physical objects and sound progressed in a very direct way, in which the visual art became the sound instruments to be physically played and create the coinciding sound work. At this point, the core research questions focused around the sound itself being a sculptural entity. To create this, I needed to define the key elements of visual physical sculpture and create criteria for which sculptural sound work should be examined. These aspects are space and physicality. Both of these elements are present in sound naturally, however, to fit my definition of sculptural sound, the elements should be realised in a manner beyond that of sound's obvious characteristics. The variety of ways this can be achieved is discussed in this thesis, however, in the portfolio works, this is achieved by the use of otoacoustic emissions. These are defined as supplementary sounds created by a healthy inner ear. The emissions can be due to certain sound stimuli or originate spontaneously.

In composing and creating, sound was realised to have many more possibilities and capabilities, which exceeds that of the physical sculptural paradigm when using otoacoustic emissions. The vast majority of portfolio pieces feature audience participation and control by what I term 'otokinetic shaping'. This is the how the audience's physical movement affects how they hear the otoacoustic emissions, allowing them the agency over how they perceive the work by their movement and navigational choices.

Chapter 1: Audio and Visual Relationships

Visual Art as Inspiration

One aspect of this research project looks at relationships between visual art, namely sculpture and paintings, and sound art or music. This segment examines the use of visual art as conceptual inspiration and how both the portfolio and the other artists have used visual arts as a tool to create sonic works. In this research, this was eventually extended to include the use of physical visual materials as sound instruments. This is covered in the next segment. The aim of the formative works in this research (*Touch Tactile and Cuboid*) was to create an experience which combines sculpture (or other visual arts), sound art, and real-time live performance. These were the first experiments in finding a relationship between audio and visual media, which eventually became focused on sound and sculpture.

There is a school of thought which suggests one should listen to music with other senses on hold for a better experience. However, this is not my experience and in Living Electronic Music, Simon Emerson writes,

> I guess that for others the hearing sense is accentuated with the eyes closed but for me this is simply not the case. In addition, I clearly perceive 'images of the music'. These are at least as far away from me as the loudspeakers. They are not superimposed as a separate landscape, but somehow integrated and even at times interacting with it: a real-imaginary symbiosis. Music – good music – does indeed take me 'somewhere else', although 'here' (the real space I am in) is still perceived clearly but reduced in 'presence' (Emmerson, 2007 p. 168).

As stated, for some, the listening experience is accompanied by an element of visualisation. By taking this idea and providing a visual stimulus for the work, the audience not only get the duality of the audio-visual relationship, but also gain further insight into the concept and core notion. Emmerson continues to quote Huberman regarding live performing:

> It's funny because for a few years I'd been going, "Don't watch me, shut your eyes and listen. There's nothing to watch." But everybody does watch me. Well, a lot of people do. And I'm always saying that there's nothing to watch and gradually I've learned that there is. They watch my face. They watch me get surprised, fed up, angry and then excited. They stand over my shoulder and watch my computer screen. It all actually gives them a way into what's going on (Huberman, 2004) (Emmerson, 2007 p. 113).

In *Touch Tactile* and *Cuboid*, the audience has the choice to examine the sculpture visually, watch the artist manipulating and processing the sounds in real-time or close their eyes to listen more intensely to the sound work, or a hybrid of these three options.

The notion behind creating a piece of visual art and sound art with the same concept or core idea was to explore ways to create a direct path to my consciousness. This idea was influenced by the techniques of action painting. The Museum of Modern Art defines action painting as,

> a common critical term to describe styles marked by impulsive brushwork, visible pentiments and unstable or energetic composition (for illustration), which seemed to express the state of consciousness held by the artist in the heat of creation (Anfam, n.d.).

The technique uses a spontaneous approach that allows a direct route from the artist's consciousness to the canvas. This creation of visuals relies on a physicality and intimacy between the materials and the artist. The artist can create in a way that allows absolute expression to translate emotions or mental state into tangible physical materials.

In the case of Jackson Pollock, the renowned figure in action painting, the work is characterised by drips and splashes of paint (Figure 1). Pollock was part of the Abstract

Expressionist movement, which took place in New York in the 1940s (Phaidon, 1996, p 506). Pollocks' method involved working with unstretched cotton canvas which he lay on the floor transforming his studio into a performance arena. This is demonstrated on the video documentary directed by Kim Evans (1987), in which Pollock states,

> I want to express my feelings rather than illustrate them; the technique is just a means of arriving at a statement. When I am painting I have a general notion as to what I am about. I can control the flow of the paint (Evans, 1987).

Pollock believed that his work was a visual translation of his consciousness. This made the creation of his art very personal to him.

Figure 1 - Jackson Pollock, Number 23 (1948) (Image Credit: Tate, London via tate.org.uk)

Harold Rosenberg believed the manner of throwing and dripping paint around the room became an event and was just as important as the painting itself. He wrote in 'The American Action Painters' in 1952,

> At a certain moment the canvas began to appear to one American painter after another as an arena in which to act… What was to go on canvas was not a picture but an event (Anfam, n.d.).

Touch Tactile features action painting and live improvised sound art, both of these mediums allow for the same amount of directness, immediacy, impulsivity and creative spontaneity, due to their focus of in-the-moment performance. This is a flow state, in which the artist inhabits. 'This state involves an intense and focused concentration on what one is doing in the present moment' and 'Loss of reflective self-consciousness' (Nakamura and Csikszentmihalyi, 2009).

My process for creating *Touch Tactile* began by playing and experimenting with paint with the only limitations being the choice of paints and tools to use for application. The performance software of the sound work was constructed in the same way, featuring a palette of pre-chosen processors and manipulation techniques ready for use. The notion was to both visual art and sound art using the same performative technique to create a unified multi-media work.

Music and Sound Art

When using visual art as stimuli for creating sound art, I consider there to be two distinct approaches to take, each with a plethora of choices, differences and intentions. Firstly, a composer/sound artist can respond to the work in a conceptual or visual sense. This requires mirroring the appearance of the work through sonic or musical means or using the same conceptual idea that the visual artist portrayed. Secondly, a composer or artist can focus on the approaches and techniques used in the process of creating the work and use or discover a method for extending the same practice in a sonic forum.

The abstract expressionism painter Mark Rothko's works are often inspirational to artists working in other mediums. His works are characterised by large panels of multi-layered paint featuring blocks of contrasting colours.

An example of using Rothko's work from the first category, comes from the works in the Rothko Chapel (Figure 2). In 1971 the Rothko Chapel was opened to the public by John and Dominique de Menil. The venue functions as a place for meditation or prayer for all faiths and a work of art in its own right, as well as displaying fourteen specially commissioned Rothko works at any one time. The mission statement states:

> The Rothko Chapel is a sacred space open to all, every day, to inspire people to action through art and contemplation, to nurture reverence for the highest aspirations of humanity, and to provide a forum for global concerns (rothkochapel.org, n.d.).

Figure 2 - The Rothko Chapel (Image Credit: Hickey Robertson/The Rothko Chapel via NPR.org)

This setting was a source of inspiration to composer and friend of Rothko, Morton Feldman, and led to the composition of *Rothko Chapel*. The work is a thirty-minute piece for soprano, alto, mixed choir of which Feldman stated,

> to a large degree, my choice of instruments (in terms of forces used, balances and timbre) was affected by the spaces of the chapel as well as the paintings (Rothko's paintings). Rothko's imagery goes right to the edge of his canvas, and I wanted the same affect with the music - that it should permeate the whole octagonal -

> shaped room and not be heard from a certain distance (Feldman quoted by Biró, 1998).

It is clear Feldman was thinking conceptually with his compositional aims in creating an accompanying sound piece to the Rothko Chapel. It is important the piece echoes some of the atmosphere of contemplation, serenity and solitude which is experienced in the chapel. However, Feldman also used much more direct musical devices, such as, phrasing to provoke the sense of mystery encapsulated in Rothko's works (Biró, 1998), and repetition to mirror the 'uninterrupted continuity' creating a selection of 'highly contrasted chained sections' (IRCAM, n.d.).

A second category and more subtle usage comes from sound artist, Monty Adkins. Adkins' work has been influenced by visual art since the beginning of his electronic music career. However, it is strictly the techniques, approaches and thought processes Adkins takes from visual art, rather than responding to certain works (Cummings, 2017). Examples of this can be found in his work *Melt* (1994) from the album *Mondes inconnus* released on Empreintes DIGITALes. *Melt* (1994) sonically implies 'force lines', or 'lines of force', which were a prevalent technique used in futurist painting (Adkins, 2007). In Adkins' more recent work, *Unfurling Streams* (2015), released on Cronica, Adkins used the idea of layers, a distinct component of Rothko's work, to think about composition. In a podcast interview by Simon Cummings, Adkins states,

> I was really fascinated by the idea of how I could create eleven layers, which had their own internal logic… and then seeing how they could be combined to create a logical musical piece (Cummings, 2017 52:20).

In *Touch Tactile,* both of these approaches were used. The sound work not only borrows its process from the techniques and ideas of action painting used in creating the visual work, but also functions as a sonic response, or perhaps equivalency, to the painting. The unique element of the work is that both mediums were created by me, meaning as well as having a response relationship, they were both achieved from streams from the same consciousness.

Sculptural Instruments

This section looks at using visual art works more directly than as inspiration or conceptual influence by using them as objects with which to physically interact to create sound.

Figure 3 - A selection of Bertoia sculptures (Image credit: John Brien/Important Records via NPR.org)

Harry Bertoia's *Soniambient* work (1960-1969) resulted in perhaps the best-known sculptural instruments or 'tonals' as he referred to them (Figure 3). As Bertoia worked and trained as a visual artist, his works inherently have a strong visual aspect. In his pieces under the umbrella of *Soniambient,* the artistic product is the sound which is created rather than the visual element exclusively. The sculptures involve long metal poles which, when pushed, collide into one another, resulting in a rich sonic texture (Important Records, 2015). Using these sculptures and many other self-built items, Bertoia recorded eleven albums containing different performances from his barn, of which a compilation was released in 2016 (Discogs, n.d.). Therefore, in this case, these sculptural instruments are used as tools for creating fixed-media sound recordings and the listener is required to use their imagination to conclude how the sculptural instruments were played in order to create the sound on the recorded media.

A different approach to exploring this relationship is the Robert Morris piece *Box with the Sound of Its Own Making* (1961). This work is a solitary wooden cube containing a speaker which plays a tape recording of Morris making and constructing the box. This includes the sounds of sawing, hammering and other noises associated with carpentry (Celent, 2014). Through this relationship of visual and audio media, the audience is transported back in time by hearing the sound of the box being made but not the sound it might make in its present form at the present time. The audience is not visually presented with any saws, hammers or carpentry materials and are required to use their imagination, with the use of the sonic composition, to envision the construction of the physical and visual sculpture.

Another piece which plays with this relationship and perhaps formed an influence on the Morris piece, is *With Hidden Noise 1916* (1963), by Marcel Duchamp. This piece is made of two brass plates and a ball of twine. Duchamp asked his friend Walter Arensberg to insert an object in the centre of the twine which, when the sculpture was shaken, would make a sound (Celent, 2014). Arensberg was never to tell Duchamp or anyone else what was inside of the work. This creates a visual component and a potential sound element which is only realised when an audience member shakes the sculpture, adding a level of audience participation. The sound that materialises, although coming from the sculptural instrument, does not allow the audience to see or ever discover what the true origin is, disconnecting the link between the visual and the aural.

In my works *Cuboid*, __—, *Nothingness* and *If; slowly*, I also explore this relationship between what is visually and physically presented to the audience, what they hear and how the heard sounds were constructed. In __— and *If; slowly*, the sculptural instruments were recorded and sampled in a studio setting and by using a sequencer various sonic processing and manipulation techniques were applied. This means the final sound product has very little sonic bonding to the sculptural instruments, however the instruments from which the sound originates are presented opposing the traditional paradigm of acousmatic music. The same is also true for *Nothingness* and *Cuboid*, however, these works were recorded in real-time performances with real-time processing and manipulation and some post-performance editing.

Live Performance

Nicolas Bernier is known for his live performative sound and visual installations. His works utilise sound, light and purpose-made sculptural instruments, which he unifies in a multi-sensory performance. In 2013, his work *Frequencies (a)* won the *Prix Ars Electronica Golden Nica*. *Frequencies (a).* It features a long surface hosting eight different tuning forks, which are docked in special holders containing mechanical equipment. The tuning forks are accurately stuck by solenoids allowing them to resonate. These sonorities are accompanied by electronic pure tones creating sonic interaction. Each independent tuning fork station is fitted with lighting equipment, giving it the ability to illuminate. The performance plays with the relationship between light and sound by both following the location of the sound source and disregarding it for a different counteracting pattern during the piece. The installation is performed via a laptop controlled by Bernier, which he uses to trigger different sequences (Bernier, n.d.).

The portfolio work, *Shimmer*, explores the light and sound relationship in a much simpler way in comparison to the work of Bernier. The repetitive flickering colours of the video intentionally move in and out of synchronicity with the repetitive sonic material. This counter-rhythm mirrors the intended themes of the piece, movement and balance. The audiovisual element moves from a collective pattern to each element having their own rhythmic voice and movement by becoming out-of-sync. Similarly, the two media drift from a balanced to an imbalanced relationship, which adds another layer of variation on top of the audience's experience of their own physical movement and balance.

Chapter 2: Embodiment

Using Space

An important aspect of the works in the portfolio is the use of space as an artistic material. This goes beyond the spatial aspect that all three-dimensional physical objects and sound materials inhabit and refers to space being used as a distinct feature of the work. This explicit use of space, along with the explicit use of physicality (discussed in later sections), is a vital ingredient in my definition of a sound sculpture.

Visual Arts

An early example of space as an artistic material comes from Naum Gabo, a pioneering sculptor originating from Russia. He is famed for his sculptures, as well as for establishing Constructivist art, and in 1920, along with his brother Antoine Pevsner, for publishing the Realistic Manifesto. The manifesto announced that space and time should be fundamental aspects explored in art, by stating: 'Space and time are the only forms on which life is built and hence art must be constructed' (Gabo & Pevsner, 1920). This is shown in his work, *Model for 'Rotating Fountain* (1925), in which he used transparent materials to include or 'invite' the space behind the work to become a part of the piece and created a kinetic element to the piece that would change over time (Treves, 2000). A second example can be found in his 1969 piece *Construction in Space with Rose Marble Carving (Variation No. 1)*. The work features a piece of rose marble that has a pierced centre, allowing the viewer to see through it. It explores 'the relationship between void and solid, mass and space through the subtractive process of carving' (Gabo, 2014).

Figure 4 - Richard Serra, Berlin Junction (1987) (Image taken by author)

From another art movement and approach comes Richard Serra, a renowned and celebrated sculptor with a career spanning over forty years and a particular influence on this research. Serra's work is concerned with architecture, balance, movement and space.

He is perhaps most known for his works which involve very large metal forms, for example *Strike: To Roberta and Rudy* (1969), *Snake (Sugea)* (1994) and *Intersection II* (1992). However, the focus of these works is not the metal structures themselves, but the negative space. The viewer is invited to travel through the space in the work and experience a 'psychological feeling of different spaces' (Museum of Modern Art, 2007). The way the metal forms lean, taper or angle can give the viewer impressions such as openness, weight or confinement. Serra uses these large steel sheets to frame space and demarcate certain shapes from the wider installation site. In framing the space Serra thinks about the relationship with the human body in his work and aims to create works in which the viewer can physically interact,

> I decided the height in relation to my body movement. At a certain point, if [the] work becomes too high, you look up [and] the physical space won't be registered with your body. It just becomes like a building (The Museum of Modern Art, 2007).

Dan Flavin's work also takes the focus away from the materials used and utilises space as a creative medium. Flavin dedicated his entire career to working with the artistic potential of light, focusing mostly on using neon tubes. In his 1963 work *Pink out of a Corner (to Jasper Johns)* he activates space by illuminating 'what is, by convention, a darkened area of the installation space. Invigorating 'dead space' with light became a powerful technique of the artist' (National Gallery of Art, 2004). Flavin manages to engulf the installation space with light and bring awareness to a space that is often seen as empty, nothingness or void. Similar to the works of Serra, the space is used by the artist to produce psychological effects on human perception through connotations linked with colour, shade and intensity.

Figure 5 - Dan Flavin, Untitled (to Cy Twombly) (1972) (Image taken by author)

Both Flavin and Serra use boundaries in their work to define the space that is to be experienced by the viewer. By defining a shape in space, they are giving what is often seen as a void, a certain physicality. They create works that use space as an experience and focus on how that experience changes as the viewer moves through the space. This allows the viewer to engage with, navigate and understand space in new and original ways.

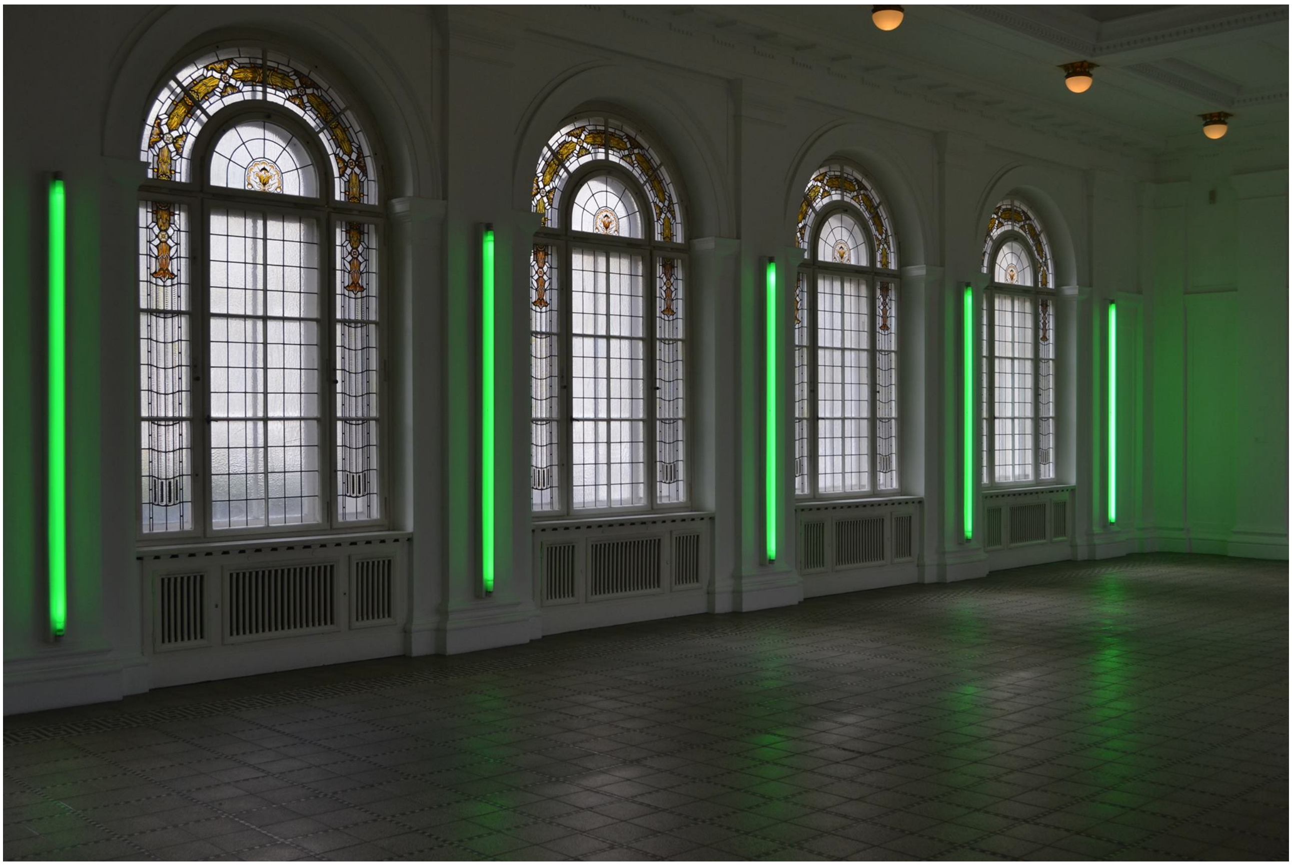


Figure 6 - Dan Flavin, Installation at Hamburger Bahnhof (Image taken by author)

Sound Art

The use of space as a key feature of the work has also been explored by sound artists. Brandon LaBelle writes on this subject:

> Activating space through implementing and inserting auditory features shifts architectural understanding. Fusing listening with spatial narratives, audition with

> inhabitation, and movements of time and body as dramas of discovery, sound installation heralds new forms of embodiment (Labelle, 2006).

Within sound art works, some artists use space as a sonic parameter; for example, Alvin Lucier's works *I Am Sitting in a Room* (1969) and *Quasimodo The Great Lover* (1970). In these pieces, Lucier explores how space can colour and affect sound. This notion is also investigated in the works of contemporary Canadian artist Adam Basanta. Basanta's works use loudspeakers, microphones, space, technology and objects to reveal sounds which are often hidden in the everyday sonic landscape of human life:

> In "A Room Listening to Itself", sound is produced through amplification techniques which "make audible" the physical relationships between microphones, reclaimed speaker cones, and the gallery's surrounding acoustic environment. Using the acoustic phenomena of tuned microphone feedback alongside recursive amplification networks, the gallery space is turned into a giant resonator that amplifies both acoustic activity and inactivity as a product of spatial relationships. (Basanta, 2015)

In both Basanta's and Lucier's works, space is used to affect or enhance sound. This is different to the aims of creating sculptural sound. In creating sculptural sound, one must identify how sound can affect or change space and create unique ways for the participant/audience to interact with spatial environments. An example of an artist working with sound using this approach, and a big influence on this project, is the artist John Wynne. Wynne is perhaps best known for his work *Installation for 300 Speakers, Pianola and Vacuum Cleaner* (2009), which was the first sound art piece to be added to the Saatchi collection, achieving further mainstream recognition for the sound art platform. Wynne's work Installation *No. 1 for High and Low Frequencies*, exhibited in 2014 at Rochelle School Gallery in London, featured sounds which were actively tuned to the venue's architectural acoustic properties, and therefore allowed the building to physically "participate" in the work. Wynne worked particularly with the physical and sonic effects gained from the tin roof resonating when it was presented with certain low frequency materials (John Wynne, 2011). Wynne used the building as an instrument in this work merging sound, space and architecture, giving the sonic piece a sculptural presence. The work also involved the audience exploring the space by moving through the installation and hearing the work from different perspectives.

The technique of tuning sound to a place or space is also used by Michael Brewster, a Californian artist who has been working on what he terms 'acoustic sculpture' since 1970 (Brewster, n.d). Brewster, whose background and education are in sculpture and visual arts, works with sound to extract its sculptural capabilities. He often uses standing waves and nodes in the location to create the sense and perception that the sound is a solid material with tangible form. In his 2001 exhibition *See Hear Now* at the Los Angeles Contemporary Gallery, Brewster's work not only looked at how to use sound, but also how to use space to further equip sound to become acoustic sculpture. Brewster himself constructed the physical space in which the sonic compositions would play in an attempt to bring out certain aspects of the sound that might otherwise not be realised (Labelle, 2006). He is not interested in the musical applications of sound and re-thought his approach when his work started to become "too musical" (LA Artstream, 2014).

Brewster is interested in how different sounds can be used to draw different lines in space, even calling some of his works 'sonic drawings'. The manner in which sound can draw was asserted in the press materials from the exhibition:

> Each portion of the [sound] spectrum exhibits unique qualities and behaviours. Low frequency sounds, for instance, which have long wavelengths, are omnidirectional and volumetric. High frequency sounds have short wavelengths and are monodirectional and linear. (Brewster cited in LaBelle, 2006)

The use of space is also an important aspect in the electroacoustic music tradition. As the composition and presentation of the music features loudspeaker arrays, with numbers from two to hundreds, a large amount of consideration goes into the practice of spatialisation, either in a fixed form as part of the multi-channel composition, in the form of live real-time diffusion or an amalgam of both. Karlheinz Stockhausen experimented greatly with spatialisation of sound. A work of note is *Oktophonie* (1991), which is one part of the Stockhausen's opera, *Dienstag aus Licht***,** but also has the capacity to be performed as an independent work. This work explored and experimented with an octophonic loudspeaker array in the shape of a cube, moving sound horizontally, vertically or diagonally at different times (Zurich University of the Arts, n.d.). A contemporary example of spatialisation in electroacoustic music comes from composer, Natasha Barrett. Her work *Hidden Values* (2012), explores three dimensional ambisonics, creating a more immersive sound aesthetic. Barrett created the *Virtualmonium*, which 'beyond serving as an instrument for sound diffusion, composers and performers can create custom orchestra emulations, rehearse and refine spatialisation performance off-site, and discover new practices coupling composition with performativity' (Barrett, 2016). The presentation of other works from Barrett and many composers of electroacoustic music is in stereo and relies on live diffusion - 'the realtime (usually manual) control of the relative levels and spatial deployment during performance' (Harrison, 1998). In both of these processes, and electroacoustic music as a whole, spatial movement is utilised to assist in articulating the sounds used. However, in the portfolio works in this research, the opposite is the case as sound is used to articulate the space.

In my work, *Cuboid*, the aim is to sketch out a spatial shape and redefine the space around a static seated audience. This piece creates a passive experience for the audience as the space around them is changed by an eight-channel loudspeaker presentation and the act of moving sound around these speakers in a cuboid formation. As there is no method of creating a sensation of a fixed shape in space with sound, the piece relies on time and moves sound from corner to corner of the shape, akin to drawing the shape in the air. This work draws on ideas from Richard Serra's work as the audience is embedded in a new spatial environment that is defined by the sculptural work. However, due to the work using the sonic medium, it gives the work a different experience due to sound’s non-visible nature. This means the audience are invited to use their imagination to visualise the exact shape, form, colour and texture of the physical boundaries of the newly defined space they find themselves in.

Space is explored is a more active way in the installation pieces in this project. The works *Nothingness*, __—, *If; slowly*, *Static*, *Shimmer*, *Shift, Grow, Forms & Perspectives* and *Seesaw* invite the audience to move around and explore the space, experiencing the range of auditory nuances this creates. The physiological and psychological effects that are gained and cause the nuances are discussed in the ’Otoacoustic Emissions and Movement’ section. Brewster describes this form of sculptural experience in relation to his acoustic sculpture work thus:

> We must shift our sculpture viewing habits from the "stand and look" behavior to an exploratory "move and listen" approach; slowly walking our ears, instead of moving our eyes, through the elaborate spaces of "the room”. (Brewster, n.d)

Creating Physicality

The second aspect in my definition of sound sculpture is physicality. All methods of sound reception require a level of physicality. However, the human hearing system is such an integral and natural part of one's everyday life that it can be difficult to imagine the practice of hearing or listening as an especially physical process. Due to this, to create an explicitly physical experience from sound, one needs to work with ways to create an effect different to the inherent hearing system, that is of notable physicality. In this research, I refer to physicality in sound as methods that fulfil and achieve this criterion.

The most obvious method of achieving physicality is by interacting with the human physiology through sound resonance. The frequencies at the extreme ends of the human hearing spectrum can be felt as well as heard and, if played at a high amplitude, will resonate directly with the body causing embodiment. Ryoji Ikeda is a Japanese artist known for his sound and video art work which includes intense digital sonorities and wall-sized digital video displays. Much of Ikeda's work involves interaction with the physiology of listener's body by utilising very high frequencies. A particular example of this is *Headphonics [VPRO Version] :: +/- [VPRO Version]* (Mort Aux Vaches, 1999). The 'ticking' sound prevalent in the beginning of the work creates an explicit sensation that the audio is emerging from the listener's head or throat area. This effect is also evoked in the piece *Data.simplex* from the 2006 album *Dataplex* (Raster Noton). In both examples the sounds are located between 15 and 20 kilohertz. A large majority of Ikeda's sounds include a layer of sonic material at above 10 kilohertz. This layer is physically felt but is often masked with different frequency sounds so isn't explicitly heard.

An album Ikeda released in 2013 on the label Raster Noton called *Supercodex* involves twenty tracks in total, with some as brief as under two minutes; the track *Supercodex 03* is 1:53 in duration. The track, much like the entire release, utilises fast abrasive cuts from intense high frequency to lower frequency sounds and rapid switches across the two stereo channels. This range of fast-moving clicks, taps and ticks with short attacks and delays, adds a tangible dimension to the sounds thereby furthering the physicality. In the piece *Test Pattern #0110,* Ikeda presents more obvious unmasked high frequency material which is located at approximately 17 kilohertz. The sensation Ikeda evokes, as well as perhaps being unnerving, delivers a sense of sound penetrating one's body leading to a unity between sound and the body.

A second artist that explores 'feeling' sound is Bernhard Leitner. A work by Leitner of particular note is *Sound Chair* (1975), in which a participant sits on a specially constructed chair with in-built speakers facing towards different locations on their body. Leitner talked about different parts of the body 'hearing' and being receptacles to sound entering them (LaBelle, 2006). He created the piece in such a way that different parts of the composition would play to different parts of the body. For example, low drones were played towards lower regions of the body and oscillated, moving to the upper torso (LaBelle, 2006).

Leitner also created a work called *Sound Suit* (1975), which, as apparent from the title, is a suit to be worn by the participant. The suit houses several speakers that point towards the body. Through this technique the sound is embodied or, in Leitner's words, 'a sound-space sculpture materialises, which accumulates and manifests itself in the body' (Leitner, n.d.).

Gascia Ouzounian in an article for Contemporary Music Review in 2006 writes on uniting sound and embodiment stating:

> Sound works designed for the body tend to bear a strong sense of ritual, conjoining physical spaces with their metaphysical complements. An encounter of real and imagined spaces, wrought in the body, produces alternating fields of vibration—at times beating positively to create an augmented awareness of self, spirit and surrounding; at other times clashing to reveal the limits of the body: that it is socially determined and determining; that it is an instrument of control; that, ultimately, it fails the user (Ouzounian, 2006).

An obscure but functional way to achieve physicality is through resonating materials or architecture. This provides the audience with the knowledge of sound's physicality, energy and power without the anatomical experience. The Art of Failure Collective utilise the energy in low frequency sound in their project 'Resonate Architecture'. The installations create their effect by playing low frequencies from loudspeakers placed inside architectural landmarks, such as the Rostiger Nagel (Rusty Nail) in Brandenburg, Germany. This projection of low frequencies causes the buildings to resonate and so become musical bodies and sound instruments. The low frequency sound is being used to physically move (vibrate) another object and thus create more sound.

Creating Immersion

Immersion is a term used by many different artists, writers and theorists to describe a range of experiences. These experiences can arise from a multitude of different disciplines and approaches. There is no agreed standard definition for immersion in artistic contexts and contemporary views reflect different concepts and methods. However, certain elements such as a degree of sensory enlivening, an awareness of physicality and the activation of space are key repeating factors through different usages. In the field of visual art, centralising on the illusionary virtual reality, Oliver Grau states:

> According to this program of illusion techniques, simulated stereophonic sound, tactile and haptic impressions, and thermoreactive and even kinaesthetic sensation will all combine to convey to the observer the illusion of being in a complex structure space of a natural world, producing the most intensive feeling of immersion possible (Grau, 2003).

Although this project is not concerned with the notion of creating virtual worlds, it is interested in the engagement of different senses (auditory, visual and somatosensory) and the experiences of immersion in which integration brings. An awareness of physicality, whether it is an awareness of one's physical presence or a somatosensory sensation, plays an important role. This is particularly true in installation art practices. Jinsil Hwaryoung Seo writes:

> Physically immersive environments expand the boundary of our vision and create imagination evoking immersive feelings from materials that affect with perceptions of dimension […] Physical installations do not include normal architectural rooms or spaces where we live in the everyday life. […] it is critical to recognize that immersive consciousness is constructed through embodied experience in the relationships among body, mind and the world. (Seo, 2015).

In this article entitled Aesthetics of Immersion in Interactive Immersive Installation (2015), Seo, states that invoking a state of heightened physicality, which is different to spatial interactions in everyday life, is important in establishing a connection with body, mind and world, and therefore an important element for creating immersion in installation spaces.

Frances Dyson writes on the immersive quality of sound:

> Three-dimensional, interactive, and synesthetic, perceived in the here and now of an embodied space, sound returns to the listener the very same qualities that media mediates: that feeling of being here now, of experiencing oneself as engulfed, enveloped, absorbed, enmeshed, in short, immersed in an environment.

> Sound surrounds. Its phenomenal characteristics—the fact that it is invisible, intangible, ephemeral, and vibrational—coordinate with the physiology of the ears, to create a perceptual experience profoundly different from the dominant sense of sight (Dyson, 2009).

In this passage, the immersive experience in which sound can create is described. Sound innately has various qualities that lend themselves to the conception of immersion. Various artists and composers use these different elements in distinctive ways to create immersion in their work. An example of this is Camille Norment's work in which a participant is invited into a physical environment (Gottschalk, 2016). In her 2001 work, *Notes from the Undermind*, which took place in a padded cell, the audience grasped poles that creating ringing sounds and interrupting their behaviour. The audience's voices and other sounds they made also interacted with the sound of the poles (Gottschalk, 2016). This work involves the auditory, visual and tactile senses, it creates awareness (activation) of the space through how sounds were interacting with the ringing poles and creates physicality through the tactile interaction with the poles and awareness of one's own body through how the sounds they made affected the poles sounds.

Artist Phil Julian (also known as Cheapmachines), describes his approach to immersive work as,

> music that "overwhelms" the listener in some way, or more specifically that completely inhabits the space it is given. This does not necessarily have to be

achieved via extremes of volume, but can come more via a physical “presence” to the sound (Gottschalk, 2016).

From using examples as the foundation, this research project has approached the creation of immersive work by exploring methods to create physical impact and bodily awareness, to activate the space and to engage the auditory sense, whilst being mindful that a more intense experience could possibly be gained with the addition of other senses.

The key method explored in this project for creating physicality and immersion is otoacoustic emissions and auditory distortions, which are explained in the next section.

Otoacoustic Emissions and Movement

Otoacoustic Emissions (OAEs) are a fundamental and crucial element of this project as a tool for creating physicality. OAEs are low-level sounds originating from the cochlea, the part of the inner ear responsible for converting the received sonic vibrations into neural signals, carried via the cochlear nerve to the brain (Figure 7).

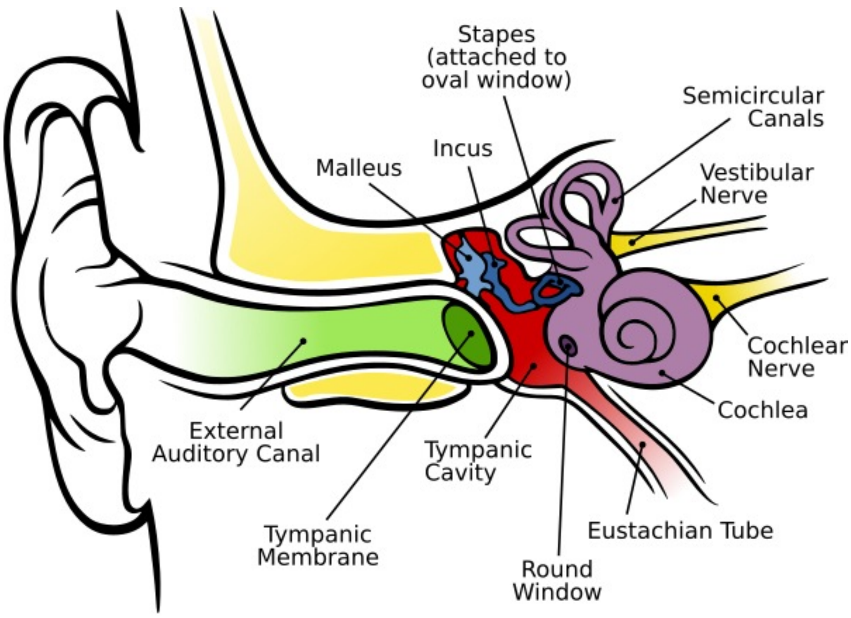


Figure 7 - Diagram of the human hearing system (Image credit: Chittka, L / Brockmann, A (2009) via Wikipedia)

OAEs can occur spontaneously or be evoked by two different sonic stimuli; firstly, a click or short burst of noise, which are called transient otoacoustic emissions (TOAE), or secondly, two independent tones, which are called distortion production otoacoustic emissions (DPOAE) (Martin, 2015, pp 547). This project is concerned only with DPOAEs, which are also sometimes called Tartini tones, named after violinist and educator Guiseppe Tartini, who is accredited with their early discovery. Tartini discovered, when performing a double stop trill on the violin (the manoeuvre of playing two notes simultaneously), that he could hear a third note accompanying the two he was playing. He concluded that it was his ears that were creating the third tone and so began using this technique as a method of creating the impression of more sounds originating from the violin (Hall III & Dhar, 2009, p. 2). A composition of his which features many double stop trills is the *Violin Sonata in G minor*, also known as the *Devils Trills Sonata*. This phenomenon was later studied by psychoacousticians and physicists. Gerhard Vieth, a German physicist, coined the phrase ‘combination tones’ in 1805, which became the standard umbrella term for describing the effect (Hall III & Dhar, 2009, p. 2). The two main theories in the first half of the 1800s were that the extra sounds originated from the instrument itself and the movement of the air created, or they were in fact a figment of the listener's imagination. In 1856, another German physicist, Hermann von Helmholtz, replied to these theories by proposing in his article, Ueber Combinationstöne, that the extra sounds were originating from within the middle ear and were objective (Kursell, 2015).

In 1978, British Physicist David Kemp carried out the ground-breaking experiment in which he placed a microphone inside his ear and was able to create the first recording of the cochlea-created sounds (Kemp, 1978). Kemp coined the term otoacoustic emissions for the phenomenon. It is now standard practice to check for the presence of OAEs in hearing tests for infants and individuals with communication issues. The existence of the cochlea response is a sign of a healthy and correctly functioning hearing system (Kemp, 2002).

There are two recognised subsets of the combination tone: 'difference tones', a frequency at the difference between two original frequencies played; and 'summation tones', a frequency at the sum of the two original frequencies played. Difference tones are the most commonly heard tones due to them being lower frequencies, which are easier to hear. There are also masking effects which occur in summation tones making them difficult to recognise (Randel, 2003). In the accompanying materials (0. Audio Examples) is an example of how difference tones work. The first two sound files (0a. 1000 Hz and 0b. 1400) are single static sine tones. The third file (0c. 1000 Hz + 1400 Hz) is the two tones played together, which, when played at a loud enough volume, will produce a difference tone of 400 Hz originating from the cochlea. The final sound file is the extra tone that the listener will have heard in the third file (400 Hz) for reference.

Returning to the musical or artistic applications of DPOAEs, although a vast amount of sound work may feature the phenomenon as a byproduct of the frequencies in a composition, very few composers and artists have explicitly intended to use DPOAEs as a feature. However, Maryanne Amacher was an artist with this intention. She described her use of, and the experience gained from, DPOAEs on the album liner notes of her 1999 release *Sound Characters (Making of the Third Ear)*:

> When played at the right sound level, which is quite high and exciting, the tones in this music will cause your ears to act as neurophonic instruments that emit sounds that will seem to be issuing directly from your head ... [my audiences] discover they are producing a tonal dimension of the music which interacts melodically, rhythmically, and spatially with the tones in the room. Tones "dance" in the immediate space of their body, around them like a sonic wrap, cascade inside ears, and out to space in front of their eyes ... Do not be alarmed! Your ears are not behaving strange or being damaged! ... These virtual tones are a natural and very real physical aspect of auditory perception, similar to the fusing of two images resulting in a third three dimensional image in binocular perception ... I want to release this music which is produced by the listener… (Amacher, 1999).

Her pieces *Head Rhythm 1 and Plaything* and *Synaptic Island* from the album *Sound Characters (Making the Third Ear)* (Tzadik, 1999), both feature sections where the only sounds heard are layered rhythms of pure tones created by analogue synthesis hardware. The listener's ears react to these sounds by presenting DPOAEs, which add another layer of poly-rhythmic material, not present in the original work. This creates an interesting experience of localisation as the listener experiences sounds seemingly originating from inside as well as outside of the head via loud speakers. Another work from the 1999 album is *Chorale 1*, which slowly evolves the texture of the emission through transforming the frequency relationship between the sounds used, affecting the interference pattern created (Kirk, 2010).

Thomas Ankersmit, a contemporary Dutch artist, also uses analogue hardware, namely the Serge Modular Synthesiser, to achieve OAEs. In his work *Stimulus 2489Hz-3295Hz,* one of the bonus tracks from the album *Figueroa Terrace* (Touch, 2014), there is a striking fluctuating panel of high frequency sounds producing very prominent emissions. A unique element in Ankersmit's practice is triggering OAE in live electronic music performance. An example of this can be heard in a recording of the piece called *Otolith* from the 2014 CTM Festival in Berlin found on Ankersmit's Soundcloud page (Ankersmit, 2014).

Another approach to exploring DPOAEs comes from Jacob Kirkegaard, who created a work in 2007 called *Labyrinthitis*. Kirkegaard used an anechoic chamber to record the response from his own cochleas when being presented with pure tone stimuli. The piece involves these recordings of Kirkegaard's ear emissions, which in turn also trigger the listener's DPOAEs. Douglas Kahn, the author of an essay which accompanies the release of *Labyrinthitis* stated, 'Kirkegaard has countered Duchamp's dictum, "One can look at seeing, one can't hear hearing"' (Kahn, 2008). Using recordings of inner ear emissions has been a continuing theme running through Kirkegaard's work. In 2016, during a residency at St. John's College at the University of Oxford, the artist recorded the spontaneous otoacoustic emissions of staff and students at the university. These recordings have led to two pieces including, *Stereocilia - for 7 Ears* and *Eustachia - for 20 Voices. Stereocilia* is a work which uses the recordings of the staff and students and explores the 'single or clusters of tones, that some ears emit without stimulus' in a compositional context (Kirkegaard, n.d.). Eustachia uses this material as a corpus to compose a piece for twenty voices. The programme note on Kirkegaard's website states:

> These recorded 'ear chords' were filtered, analyzed, and then interpreted for voices. The work connects two intimate organs of our body: the ear and the throat. The ears are the composers, the throat and mouth are the performers (Kirkegaard, n.d.).

The method used in this research project consists of combining different sets of frequencies to create interference patterns and beat frequencies. These frequencies are spread across different loud speakers creating a moving effect in space. The interference patterns do not strictly create a physical sensation alone but can create a sonic effect that makes the listener more conscious of the otoacoustic emissions and how sound moves in space. This is one of the reasons the works are intended to be heard via loud speakers and not headphones. In many of the portfolio works, various sets of these frequency sets are layered which causes a distortion effect or 'overloads' the response and creates a lot of physical pressure on the head. The actual notes being produced by the cochlea are unrecognisable, which is unimportant as the compositional aim of the use of the phenomenon is to create the most physical effect possible in this unique way.

An artist who uses beating or interference patterns in his work is Brian Connolly, an Irish artist and composer. Connolly's composition repertoire includes electronic works evoking transient otoacoustic emissions (TOAE), and acoustic instrumental pieces which explore DPOAEs. The artist's work *Ear Walk* (2016), an installation which was presented at the Sound and Sculpture Conference 2016 organised by me, involves the audience member walking around a space in the middle of an eight-channel sound composition. The listener wears one single headphone and listens to the interference patterns created when sound from the headphone and the sound from the speakers interact.

In the portfolio works, the ratio of 1:1.2 is used as a starting point. This creates a Cubic Difference Tone (CDT):

> The CDT is most clearly audible when the ratio of the acoustic signals, f2/ f1, lies between 1.1 and 1.25. Ratios within this range coincide with musical intervals between a major second and a major third. And, as we expect with musical intervals, ratios below 1.14 produce auditory roughness (or dissonance from the musical perspective) (Kendall, Haworth & Cadiz, 2014).

However, the frequencies are then intuitively 'tuned' to create the most intense physical effect possible, with a disregard for the musical interval, harmony or exact difference tone achieved in the process and therefore very rarely are still at the difference of 1.2 in the final version. For example, in the portfolio work *Seesaw*, the source frequency is divided by a pseudo-randomly generated number between 1.051 and 1.2 via computer algorithm.

The portfolio contains works which have explored different sounds as stimuli. All of the above examples, excluding Kirkegaard's ear recordings, use synthesis as a trigger to produce the ear tones. The work *If; slowly*, differs from this by using recordings of concrete objects. The sounds in the work originate from the visual sculpture, which is constructed of steel rods, which are used to mark out space in the installation situation. Using these sounds give rise to some challenges such as creating a clear pitch relationship between the different sounds. This was overcome by creating a Max patch to pitch shift the sounds and intuitively tuning the sounds to create the most intense physical effect. Aside from this work, the majority of DPOAEs evoked in the works are created using sinusoid waves. This is because it is very hard to pinpoint the location of where the sound originates and therefore, it causes the sensation that sound has completely filled the space around the listener, leading to a powerful sense of immersion. The accepted fundamental theory on how sound is localised is called the Duplex theory established by Lord Rayleigh in 1907 (Strutt, 1907). This is defined as 'using both interaural level difference and interaural time difference together in order to provide binaural information' (Balkany and Zeitler, 2013). The interaural time difference is the time relationship between when each ear receives the signal and the interaural level difference is the relative volume at which each ear receives the signal. The interaural level difference is only useful for detecting 4kHz and higher and therefore is used in these works

(Hartmann et al, 2016). The interaural time difference calculations are made using transients or onsets in the sound. In using steady-state sine tones, neither of these aspects are present. This was found by Rakerd and Hartmann (1986) in their study, 'Localization of sound in rooms, III: Onset and duration effects'. Localisation cues are also found in the spectral information of sounds, particularly in the transient partials. Sine tones are particularly short on spectral information as they focus exclusively on fundamental frequencies. It was shown in 1936 that the accuracy of localisation is greatly reduced when there is less spectral information in stimuli (Stevens and Newman, 1936).

Movement is paramount to how DPOAEs are used in the portfolio installations. The original term used in this project to describe this unique compositional application of otoacoustic emissions is 'otokinetic shaping' ('oto' meaning the inner ear and 'kinetic' meaning movement). The word 'shaping' illustrates the level of input the audience member can have on their perception or experience of the given sonic material through their movement and something I intended to make explicit use of. The shaping can be perceived as the frequencies are being altered, filtered, changing timbre, changing rhythm or disappearing. My focus with using otokinetic shaping in the works is on full body movement. The audience are invited to experiment moving in any direction, leaning in any direction, crouching down, reaching out, lying down, moving across the floor, or whatever their imagination permits. The exploration threshold of my works is very small, meaning any slight movement of the listener's body could adjust how they perceive the rhythmic elements, frequencies and frequency relationships, timbre, and number of sounds involved in the material. A reduced version of this, regarding only head movement, is discussed in Alex Chechile's article for the International Computer Music Conference (2016) entitled, The Ear Tone Toolbox for Auditory Distortion Product Synthesis. Chechile writes:

> while immersing the listener in an interactive sound field… slight head movement causes distortion products to appear, disappear, and change timbre (Chechile, 2016).

A powerful advantage to working with otoacoustic emissions, particularly when using the phenomenon of otokinetic shaping, is the portability of the work. As the connection is between the sound and the ear, the physical effect does not change depending on installation venue; however, the spatial element does, but this is allowed and encouraged, as the work is a way of listening to different spaces. Otokinetic shaping is a collaboration between me presenting artist materials, how the space 'interacts' with the sonic materials, and how the audience choose to explore the space to activate or manipulate them.

Chapter 3: The (Non-)Role of the Artist

A thread running through the majority of the portfolio works involve the artist/creator giving up much of the control and artistic/compositional authority to other aspects involved in the work. This questions and examines the role, or the non-role, of the artist/creator. The works explore novel audience participation, giving the audience control over how they perceive and experience the work, and in some cases, the agency to create their own personal composition from the installation environment presented. This changes their role from passive to active (audience member to participant) and creates a bi-directional relationship between the work and the audience. Many of the installations involve the use of computer algorithms, which feature aspects of randomisation. This creates a freeform collaboration between the audience and their ascendancy, and the algorithm and its indeterminacy. The artist establishes the boundary conditions for the work, facilitating the interaction of the audience and the installation without pre-composing or pre-determining this relationship. This collaboration is similar to what Samantha Horseman titles a 'tri-polar dynamic between sonic, physical and perceptive occupant' (Horseman, 2012). The aesthetic of the works is purposely minimal to reduce the artist's/creator's imprint on an experience which should be led, created and curated by the audience members themselves. The works are intended to be the simplest, purest and most authentic way of realising the original concept of the work, thereby building a platform for the audience to gain the most effective personal experience.

Audience Participation

Artworks through many different disciplines and mediums have included levels of audience participation, from stand-up comedy to performance art and video art to sculpture. One could argue that viewing or listening to any artwork is a form of participation that is needed to experience a work. However, this research is focusing on the distinct use of participation as a vital attribute of the work in which the work would not be complete or functional without it. Marina Abramovic, a widely renowned and acclaimed artist, is an authoritative example of this. Her pieces *Rest Energy* (1980) (a collaboration with artist Ulay, real name Frank Uwe Laysiepen) and *Rhythm 0* (1974) surrender almost complete artistic control to the lay participant. *Rhythm 0* (1974) involves a table of objects, which the audience/participants are invited to use in which way they choose with Abramovic's body. *Rest Energy* (1980) utilises a bow and arrow and invites a participant to pull back the bow with the arrow pointing at the artist's chest. These works examine human nature and create a dramatic, and possibly life-changing, experience for both the participant and the artist.

The Fluxus movement was a hot bed for works which explored participation. It featured works which share the vulnerability and the artist-participant relationship explored in the pre-mentioned Abramovic works, with pieces such as *Cut Piece* (1964) by Yoko Ono. Another member of the Fluxus movement, Nam June Paik, who is best known for his pioneering work in video art, created works which relied on technology to build that interaction with the viewer. *Magnet TV* (1965) is an interactive sculpture in which the viewer has direct input on the appearance of the work. The piece is constructed of a television set and an industrial size magnet, which are placed on top of the TV with the invitation to the viewer to move the magnet around the set, therefore manipulating the abstract forms which appear on the television. A second piece by Paik entitled *Participation TV* (1963) relies on participants to create sound, as the work invites viewers to use microphones from which the signal is then converted into abstract real-time imagery shown on an appropriated television. 'Paik not only made this passive device the interactive device, but also changed passive viewers to active participants' (Ha, 2015). A video demonstration of the piece can be found on Vimeo, uploaded by Bright Eye Cinema (Bright Eye Cinema, 2013).

Due to the success of programming languages/environments, accessible and reliable audiovisual hardware and various ways to connect networks, the creation of technological interactive installations is rather unrestricted. Attributable to this, there has been a rise in audiovisual works in recent decades, which perhaps take inspiration from works such as *Participation TV*. Many of these works require gathering data from a certain element (or elements) of audience participation and using that information to control an aspect or parameter of the sonic or visual media. A common element is the physical movement of the audience/participants in an installation space.

Flock (2007) is a work by Jason Freeman that takes data from participant's movement and applies it to musical notation. The performance piece, written for saxophone quartet, video, electronic sound, dancers, and audience participation, uses overhead video camera technology to plot the location of the participants and generate new material or implement changes to the musical score in relation to their movement.

> A variety of algorithms are used to generate the notation. Sometimes, each participant's x and y position generates a note of corresponding measure position (x) and pitch (y). Other times, the distances and angles between saxophonists and other participants generate the notes; as more people come closer to a saxophonist, his real-time music notation becomes denser and more complex. And often, participants create motion trails on the notation as they move over time. Dozens of other algorithmic parameters control everything from dynamics and articulations to pitch-set quantizations and point clustering (Freeman, n.d).

This feature of group movement in space is also explored in the Dávid Somló work, *Mandala* (2016). In this work, each participant has a sound playback device and is instructed to travel around their own pre-designated shape marked on the ground. The movement of each participant will actively change how they hear the sounds originating from other participant's devices, but will also change how others hear the sounds originating from their sound devices. The piece explores group interplay, creating an original spatial composition at each performance. *Mandala* is 'part immersive sound composition, part intimate choreography, part group meditation' (Somló, n.d.).

In the 2016 work *Embodied iSound***,** by Marcelo Gimenes, smart mobile phones were used as instrumental devices in the performative installation. The work gives the participants certain control over various parameters affecting the sonic material originating from the quadraphonic loudspeaker set-up. The location of the participants in relation to different points in the space affects the spatialisation of the sound. The participants also have other controls through the use of the phone's gyroscope and buttons as part of the purpose-built application interface.

In the works in which otoacoustic emissions are used, participant movement is also crucially important but constructed and realised by an entirely different method. In this portfolio, rather than technological interfaces gathering data in order to affect a change in the sonic outcome, the works use the natural processor of the human hearing system (through DPOAEs) to activate the sonic modulation. The nature of this phenomenon means the audience automatically become physical participants in their own experience as their ears start to produce sounds which only they can perceive. Unlike the pieces discussed previously, these works focus almost exclusively on how movement in space changes sound perception, spatial perception, composition and the experience for each participant individually and idiosyncratically. The works do not rely on the collaboration or any level of group networking to achieve the experience as each member of the audience is encouraged to embark on their own personal experience and in the majority of works, compose their own sonic work and spatial experience from the sound materials through their navigation choices using otokinetic shaping. Their actions in forming their private personal work affects their own experience only. The duration of the work is decided by the audience/participants; as the experience of the space becomes part of the musical structure, audience members can enter, leave and return to the installation space whenever they wish.

This research is not a scientific study with the intention of proving the existence of otokinetic shaping, it is research exploring the unique and creative application of it; however, the sensations experienced when moving in an environment in which DPOAEs are being evoked have been described by many people at the three different conferences at which I have exhibited these works (See Appendix A). The reactions vary from expressions of enjoyment and interest to feeling uncomfortable and uneasy, however, the otokinetic experience is always accomplished.

As discussed in the 'Otoacoustic Emissions and Movement' section, Amacher worked explicitly with the cochlea response with the core intention that 'the music… is produced by the listener' (Amacher, 1999); however, a person listening to Amacher's works has no control over what their cochlea produces as this is decided by the frequency ratios chosen by the artist. In this research, the emphasis is on the listener having the control by not only creating work that originates from the listener's inner ear but also giving them the direct agency to change their experience. The work is redesigning the listening experience not only as something in which a listener is very physically active, but one in which they have important choices.

Indeterminacy and Algorithm

The use of audience members changing their role into active participants invites a certain indeterminacy in what they personally experience; however, the stimulus they are using to achieve this experience is still decided by the artist/creator. Because of this, the project intended to explore a further layer of randomisation: realised through computer algorithms. The later triptych (*(non)Static*, *Shift* and *Seesaw*) explores a multi-layered indeterminacy; the sound can be interpreted, manipulated or changed by the movement choices of the audience, but also, the actual stimulus is changing in a random manner, therefore creating a more extreme difference in each person's experience.

In dealing with randomness in music there are several terms that composers use to describe indeterminacy in their process or work, which can mean slightly different things. Below is a brief summary by Sever Tipei:

> **Chance music** - indeterminacy at the level of composition. During the writing of the piece, the composer employs a chance procedure. Once the work is finished, the score is followed exactly in the same way all traditional music scores are.

Aleatory music - indeterminacy at the level of performance. The performer is asked to make decisions which will affect either details or even the form of the piece.

In many instances elements of chance music and aleatory music co-exist in the same work.

Stochastic music - indeterminacy at the level of composition but involving strict mathematical tools (stochastic distributions). (Tipei, n.d.).

These definitions perhaps have their origins in *Die Reihe I: Electronic Music (*1958), particularly from the chapter titled *Statistic and Psychological Problems of Sound,* in which Werner Meyer-Eppler describes aleatoric modulation.

A key, and widely associated figure in a both aleatory and chance music, is John Cage. Cage used his interpretation of the I Ching to generate musical material. In the website version (complied by Dan Baruth) of the book *I Ching or Book of Changes* by Hellmut Wilhelm and translated by Cary F. Baynes, the system is described as:

> eight trigrams are symbols standing for changing transitional states; they are images that are constantly undergoing change. Attention centers not on things in their state of being - as is chiefly the case in the Occident - but upon their movements in change. The eight trigrams therefore are not representations of things as such but of their tendencies in movement (Wilhelm, 2011).

The most famed piece created with the composer's *I Ching* derivation and perhaps his most famed piece featuring chance operations is *Music for Changes* (1951). In this work, parameters such as 'tempi, dynamics, sounds and silences, durations, and superimpositions were decided by the chance system' (John Cage Trust, n.d); however, after the composition of the work, these parameters remain static. The chance or randomness aspect of the piece was purely in the process of creation and each performance of the work is intended to be the same, meaning this work is chance music. This is in contrast to *Winter Music* (1957) and *Music for Piano* (1955). In these works, the performers have much more freedom over components like dynamics, tempo, resonances and the overlapping of the material. In both pieces the performer(s) can overlap different pages/pieces of events. This freedom given to the performer(s) ensures that each performance will be different, creating an aleatoric work.

A second leading proponent of indeterminacy is Iannis Xenakis. Xenakis' work is fundamentally different from that of Cage's. Xenakis' use of indeterminacy was centred on his use of mathematical theories to control the large-scale movement of materials as well as the distribution of individual elements within these global features. Xenakis used Boolean algebra, game theory and stochastic techniques.

> Xenakis opposes Cage's unlimited use of chance. In contrast to Cage, he claims that a composer should determine at least the macroscopic shape of a composer, leaving each microscopic detail to the determination of chance (Steib, 1999, p. 18).

Xenakis' interest in using mathematical formula in music developed into using a computer program to generate what he called stochastic sound synthesis and dynamic stochastic sound synthesis. He used these synthesis techniques to create sound materials for the *Polytope de Cluny* (1972), *La Légende d'Eer* (1977) and *GENDY3* (1991). In these works, the algorithm controls the microscopic elements of the work creating a randomised sound palette. This is particularly apparent in *Polytope de Cluny*, as the concrete sound of ceramic wind chimes is heard in electronically manipulated form. Xenakis also used stochastic synthesis to generate pitch graphs used to create scores for instrumental music, such as *Mikka* (1971), *N'Shima* (1975) and *Mikka "S"* (1975) (Luque, 2011).

The use of mathematic formula is also used in the composition of electroacoustic works as used by the composer Barry Truax. Early on in his career, Truax was 'exploring the possibilities of using Poisson-ordered distributions in the generation of microsound' (Clarke, Dufeu, Manning, 2014). The Poisson distribution predicts the likelihood of an event occurring in a certain time frame, if the average is known. In the creation of *Riverrun* (1986/2004), Truax utilised a computer program he had created, entitled the GSX, to generate granular synthesis with which the piece is constructed. Much like the notions of Xenakis, this work, and others of Truax, allow randomness on a microscopic level, but the composer still holds full control on the macroscopic shape and form of the work.

There are some similarities between some of these pre-mentioned notions and some of the works in the portfolio. In much of Cage's work there is 'a balance between the rational and the irrational by allowing random events to function within the context of a controlled system' (Jenson, 2009). Similarly, this can be said for the works in this research portfolio, although the elements which are fixed or random are different to the microscopic or macroscopic ideals of Xenakis. In the work *Crossfade*, any frequency is allowed to occur within a set range of numbers. However, it is important to remember that it is never completely random. The various types of randomness discussed here are pseudorandom, whereby they can be highly unpredictable, but never truly random. These numbers have only been set, as such, to ensure there is an adequate to extreme physical effect gained from the otoacoustic emissions triggered by the ratio within the frequency set. In an ideal scenario, the computer algorithm would have complete freedom to generate any frequencies possible, but there needs to be some input (in an algorithmic form) to ensure otoacoustic emissions occur. A work from the portfolio which expresses as much control as *Music for Piano* is *Forms and Perspectives*, in which six different sound events are triggered at any time and in any order by algorithm. This allows for overlapping of events and a variable duration of the work. On the other end of the scale is *Static*, where not only is there no change to the sound at all, the frequency of the sine wave is not fixed for each performance. The only possible recognisable feature of this work is in the range of pitches which the artist/creator has chosen and the range of ratio relationships which can be generated, although this is almost completely impossible for a listener to detect. The diagram below plots out the level of randomness in work category (figure 8).

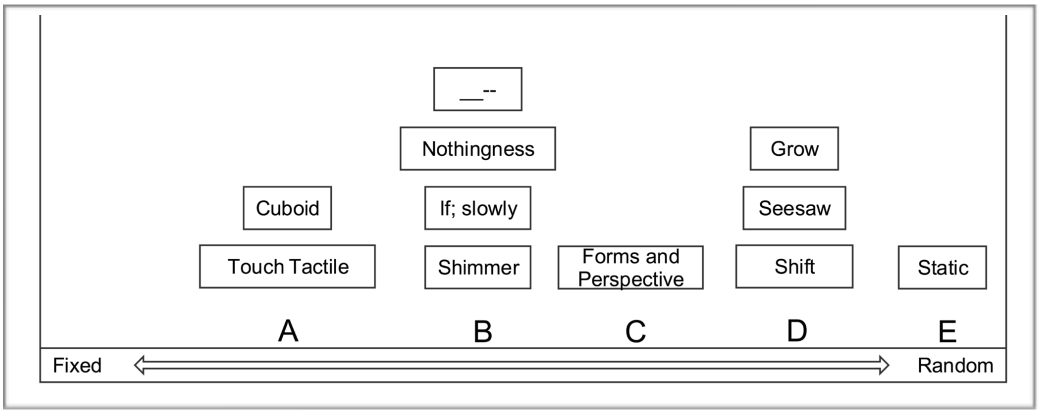


Figure 8 - Portfolio pieces grouped by level of indeterminacy

A - The shape of the work is pre-decided. The indeterminate elements come from a small amount of freedom in improvising of the microscopic aspects of the works.

B - The work may have included some improvisation in the composition stage but is completely fixed at 'performance' stage. The pieces rely on the audience's use of otokinetic shaping to create indeterminacy in their own personal perception.

C - The piece is made of a number of fixed set sonic events. Each event can be triggered at any time via a randomising algorithm. This also includes otokinetic shaping.

D - A randomising computer algorithm performs live, indicating the piece will never be the same in two situations; however, some elements are fixed such as the duration each frequency set is played and how the work transitions to new sets. This uses includes otokinetic shaping.

E - The work involves no changes, therefore has no elements which can be fixed or indeterminate. The frequency set used in the work is randomly created in the installation situation and remains static. This means the piece will be different in each installation setting. The work also utilises otokinetic shaping.

Using the framework constructed by Sever Tipei quoted at the start of this section, one could comment that a majority of the portfolio pieces are aleatoric in nature. This is because it is at the point of performance in which the elements of indeterminacy are activated; however, this doesn't always include a performer, often this is carried out by a computer algorithm.

Minimalism

The installations are created to be as reductive and minimal as possible. There is a strong link between creating works of minimal aesthetic and works which in some way explore the diminishing artist/creator's role. By reducing down to the bare concepts or key aspects of a work, the creator is reducing elements which bear their imprint. By creating the simplest version of a concept or artistic notion, it allows the audience, or other elements, to have more control over the variables which otherwise could be controlled by the artist/creator. Examining the portfolio works specifically, listening to a reductive version of the work encourages the listener/audience/participant to notice and appreciate every tiny nuance and subtlety involved in otokinetic shaping and its effect heard in/on the ear.

A key example of this is *Music on a Long Thin Wire* by Alvin Lucier. Tim Perkis discusses this work in the book *Art and Complexity:*

> It's difficult to imagine a more passive notion of composition. Lucier doesn't control anything about the process after it is set in motion. The consequences, and the musical interest, are purely the result of physical law and the contingencies of the moment: the wind, the temperature, the imperfections of the string (Perkis, 2003).

In this work, a long thin wire is stretched across a space with an electrical sine wave passed through it. The sound created by this system comes only from the wire 'playing' itself.

A piece with a similar aesthetic is the early Steve Reich work *Pendulum Music* (1968). This work involves dropping a selection of hanging microphones suspended from the celling in a pendulum fashion. The microphones pass a selection of speakers lined up below causing feedback. Each microphone is traveling at a slightly different speed and at a slightly different angle, causing an unpredictable sonic outcome. The sound becomes totally reliant on the physics of movement until all the microphones have come to a halt and the sound becomes static.

In these works, and the pre-mentioned Cage piece *Winter Music*, the minimalism comes from the elements the artist creates. The artist is setting up a process or a system for unplanned sonic events to occur. In the Cage work, it is the performer which is the 'manager of the randomness' through their interpretation of the score, but in Lucier and Reich's work, it is the nature of the physics relating to several different variables in the setting. The majority of the portfolio works also function with these aesthetics, in which the elements are assembled and other aspects and variables recreate the work. In the portfolio, it is the audience that take the place of the performer or physics by traveling around the space and otokinetically shaping their perception of the work in their own indeterminate fashion, along with the use of pseudorandom computer algorithm.

In the process of creating such a work, three aspects need to be present for it to be completed and successful.

1) Sonic Materials
2) Installation Space
3) Audience Movement

These elements feed into each other as shown in the diagram below (Figure 9).

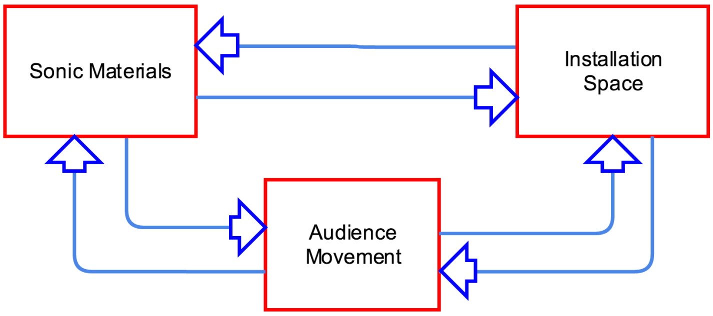


Figure 9 - Elements of my composition process

In, for example, fixed media composition, the work can be declared finished when the composer has completed the aims and intentions of the work. There is still the process of audience interpretation, which relies on variables such as size of space, speaker array and the listener's placement in the space; however, the amount of change the piece might sonically achieve in a traditional electroacoustic fixed media presentation is slight in comparison to the portfolio works, in which the audience have an active role in the composition. In relation to this, the portfolio works can never really be declared finished in the same way. The portfolio works need to be heard, perceived and shaped by the audience for them to be completed or successful, and each installation situation is different and involves distinct elements of indeterminacy, and because each person's navigational choices in the installation are different, the works evolve and change in every situation. Due to this, this approach and aesthetic significantly diminishes any artistic imprint or control I have over the work as a creator, challenging the role of the artist.

Chapter 4: Works

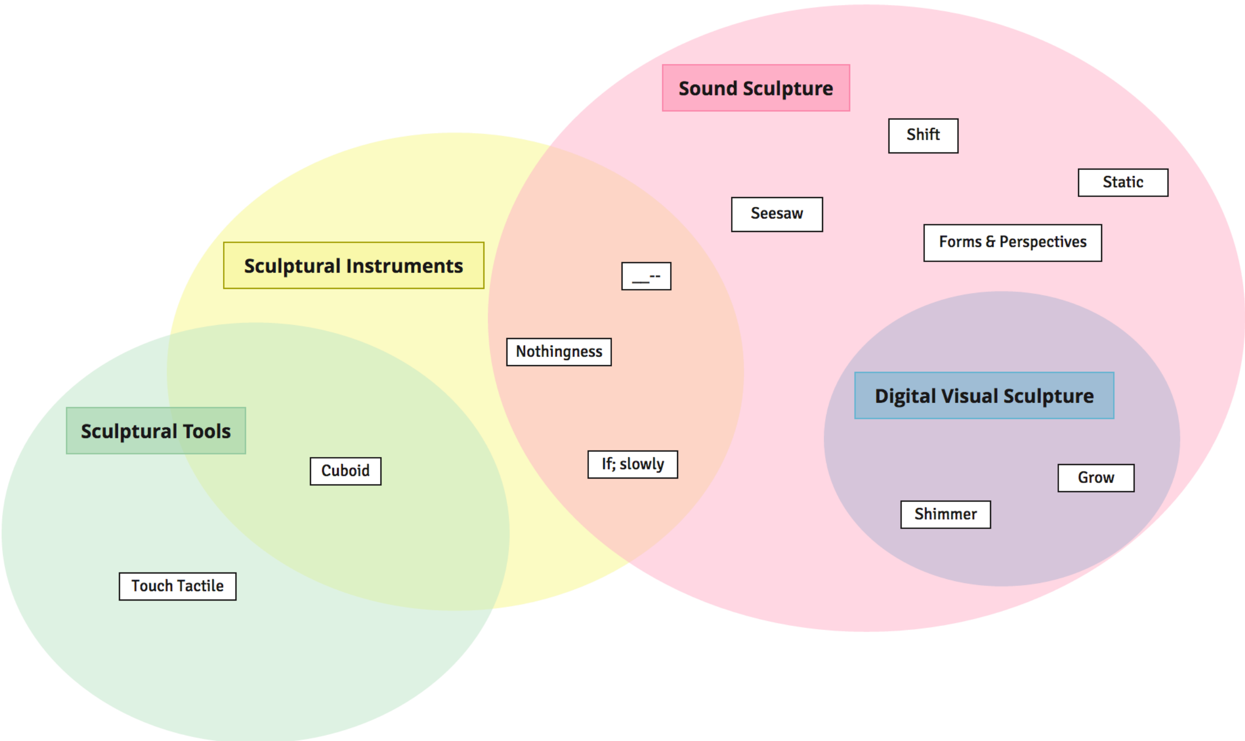


Figure 10 - Venn diagram of pieces

This chapter discusses the eleven works created in this research project in more detail, covering artistic intentions and the creation process. These works fall into 4 different categories as follows:

1. Sculptural Tools - The pieces in this section involve the use of visual imagery or objects as tools for creative stimulus in composition.

2. Sculptural Instruments - The pieces in this section involve the use of physical visual objects as instruments to create sound. This could be through striking, beating, rubbing or grinding the objects.

3. Sound Sculpture - The pieces in this section involve the use of sound as a physical and spatial entity, taking on the role of physical object sculpture.

4. Digital Visual Sculpture - The pieces in this section involve the use of digital video media and utilising said media as a sculptural entity.

Sculptural Tools

Touch Tactile

Figure 11 - *Touch Tactile* painting

Touch-Tactile is a work that falls clearly into the sculptural tools category. This is because it uses visual art, in this case a painting, as a compositional stimulus in the creation of sound art.

The work is a multi-sensory installation and performance piece. It combines a fixed-media action painting and real-time improvisational musical performance using sounds from an unconventional object. The work can also function as two fixed-media elements, which can be installed using headphones and a television screen.

The painting features small gestures of black, red and orange paint. These marks were made by diluting household paint with water and dripping the liquid from the end of a wooden stick. They are joined by large splashes and trails of paint which were thrown and dripped straight from the paint container. The structure of the sound improvisation very loosely follows the structure of the painting as it is read from left to right, but the core intention was only to capture the general aesthetic and techniques used in the painting. The chosen sound object for this piece was a sponge scourer. I considered it important that the sound performance should involve a level of touch and 'hands-on' manipulation from me, as the performer, mirroring that used in the creation of the painting. I experimented with a contact microphone in various ways, until I realised a rough material rubbed on the microphone, along with real-time effects and processing, would create an interesting gestural sound to match the aesthetic appearance of the painting. The documentation of the performative elements of action painting are the painting itself. The sound intends to capture the frantic creation of the painting but also the gestures of the paint through small fragments of sound that layer and overlap. The layering technique creates a sound-world with both complementary and contrasting textures that remain individual, but also remain strongly related. Sounds in the piece that originally start as small fragments soon become a powerful, rich and dynamic web of soundscapes.

The core aim of the piece was to explore how creating visual and audio media with the same performative systems taken from action painting, and particularly the work of Jackson Pollock could create a more cohesive multimedia work with a stronger bond between the two elements. It is with these ideas of integration in mind, that I decided to create all elements of the work. There is no audience participation in this work, so the ideal audience outcome would be to experience the close relationship between the two media and free fully engaged and absorbed by the gestural aesthetic. There was also no attempt to create an immersive experience in this work.

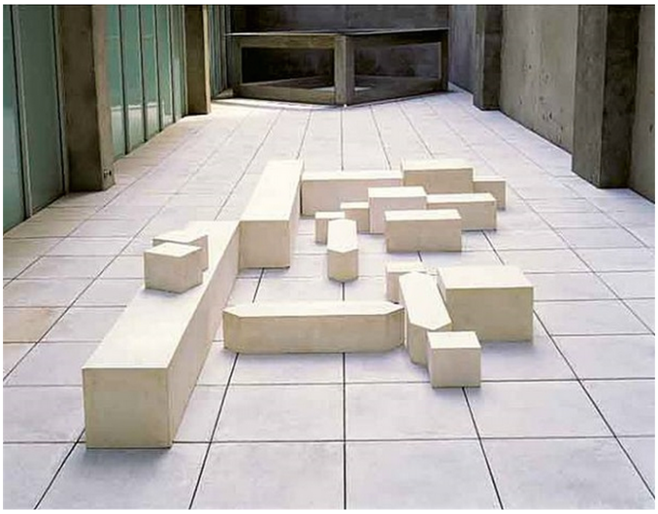
Sculptural Tools/Sculptural Instruments

Cuboid

Figure 12 - *Cuboid* ready for live performance at *Electric Spring Festival* (2015) at the University of Huddersfield

The next work in the portfolio, Cuboid, conforms with the two categories, sculptural tools and sculptural instruments. This is because the piece aimed to explore a further relationship between sound and sculpture by utilising the sculpture as a compositional tool as well as directly being used as an instrument for sound creation.

Cuboid is an eight-channel performance piece, which now mainly functions as a fixed media stereo recording for headphones. This work sets out to use various aspects of sculpture and use them in the creation and composition of sound and music. One can assign many different musical or sonic parameters to visual ones in order to create a relationship between the two media. For example, one could take a famous skyline and map the different heights of the architecture as viewed from left to right and apply those changes to the amplitude changes in the duration of a musical piece. Visual information can quite easily be translated this way into musical inspiration. In her paper, *Composing from Spectromorphological Vocabulary: proposed application, pedagogy and metadata* (2009), Manuella Blackburn details how Dennis Smalley's language for describing and analysing electroacoustic music, *Spectromorphology* (1997), can be used as a compositional tool. Smalley's system uses visual shapes and symbols to depict the evolution, progression, or movement of sound over time. By using these visual representations of sound and applying them to the three-dimensional world, one can draw comparisons between sculptural works and these depicted 'blocks' of electroacoustic music gesture. For example, looking at the 1995 sculpture, *Separated, Catalogued, Sealed, Eventually Joined,* by Barry Le Va (Figure 13), and taking an example of a *Morphological String* - a technique used by Blackburn in her work *Kitchen Alchemy* (2007) (Figure 14), the visual similarities are very evident.



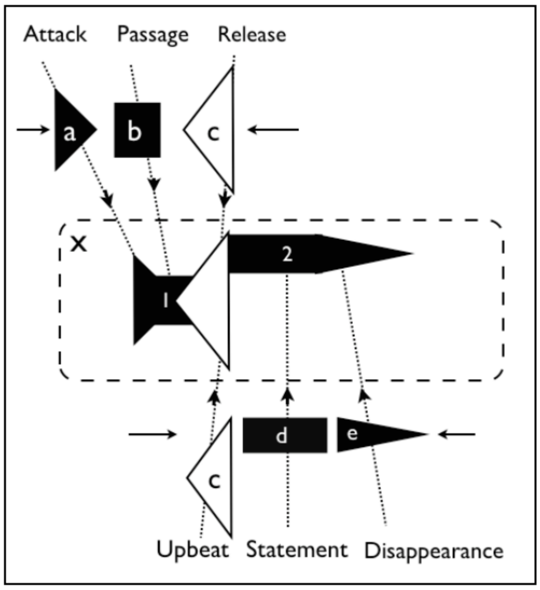


Figure 13 - Barry Le Va, *Separated, Catalogued, Sealed, Eventually Joined* (1995) / **Figure 14** - Blackburn's example of a Morphological String (2009)

From this it is deemed that an artist could use a sculpture to compose one or more musical gestures depending on the size and shape of the sculpture. The sculpture could be used as a graphic, or a physical score, and read as if the shapes are sound over time. Within *Cuboid*, this idea was explored on a very basic level by using one shape, and due to the very limited gestural identity of using only one shape, exploration was needed to discover different ways sound and musical convention could represent that shape. With this process in mind, and because the sculpture was created first, the beginning of the process could be described as 'sculpting with sound' rather than simply sculpting. The resulting sculpture completely dictates what music will manifest from it so it is impossible to create sculpture without also deeply considering the musical implications of the work. This means that as soon as the very first sculptural idea is being conceived, the limitations on the sonic element begin to form and many of the compositional choices are determined. This is because of the importance of the material and size of the sculpture due to its effect on the sound possibilities of the piece. For example, if the sculpture was made from a soft material like sponge, but had physically extreme angles or spikes, it would be very difficult to realise the potential compositional and gestural ideas in said sculpture sonically with a material which did not allow for much attack. Another way to consider this process is that music is composed through the sculptor's hands. The process in practice becomes very non-linear as no work can be carried out until both the sculptural and sonic elements are considered and there is always movement back and forth to different parts of the process.

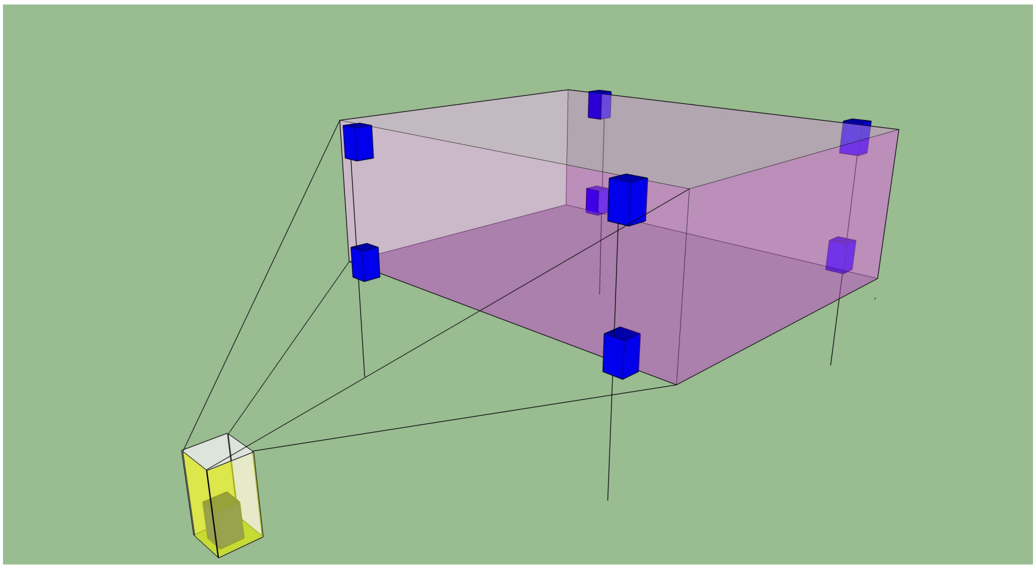


Figure 15 - Graphic representation of visual and sonic sculpture

The piece is presented as a live real time performance with the cuboid sculpture played in front of the audience recorded into a buffer and processed to form a musical composition. This piece was composed for eight speakers creating the shape of a cuboid. This intended, similarly to Richard Serra's works, to change the shape of the space the audience could feel. It also aimed to convey the shape to the audience and act as a sonic expansion of the visual cuboid sculpture (Figure 15). This is done by tracing the space with sound over time. If one uses all the speakers at once, the sound location becomes unidentifiable and the notion of shape diminishes. By outlining each speaker one by one over time, the audience can grasp each separate location and by memory draw the shape they are in. This was aiming to create a sense of immersion in the audience by manipulating the audience's perceptions of dimension (Seo, 2015). However, through the nature of tracing sound in this way, the audience may be aware of the sounds moving around them, but not have a feeling of being inside a shape. There is also a lack of the other aspects that were accepted at the start of this thesis as important factors in creating true immersion, such as physicality.

Another method of representing the shape was through the symmetrical structure of the piece (Figure 16), which aimed to echo the symmetrical nature of squares, cubes and cuboids.

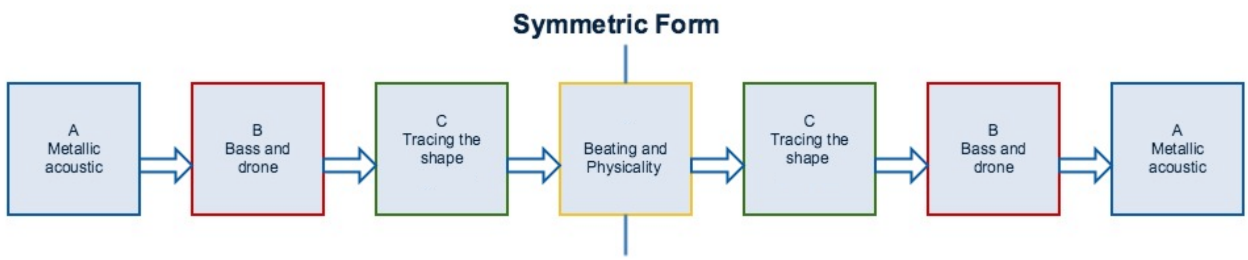


Figure 16 - Cuboid Musical Structure

The ideal audience experience for this piece is to have the sensation that physical space that they are in is changing and becoming the shape of a cuboid. This piece involves no audience participation. The focus is on listening and experiencing the different spatial and physical aspects of the work giving it a sculptural identity.

Sculptural instruments/Sound Sculpture

The next three works (*Nothingness*, __— and *If; slowly*) detail an important point of change in the progress of the aims and research objectives of the project: from works in which the visual sculpture and the sound work are equally important, to works where sound takes precedence over the physical sculpture and the visual elements become an accompaniment. These three works use the materials of the visual physical object only as instruments, meaning there is no conceptual link between the two mediums. The visual objects function to represent space and physicality, which the sound works intend to exhibit.

The compositional style for the sound sculpture in these works is still narrative-based, although they are installation pieces which are intended to be looped indefinitely. This does allow the audience control over how much of the piece, (or how many times), they hear and interact with the work. It is my intention for the listener to experience at least one complete iteration because different sections in the pieces explore different elements of physicality. For example, in *Nothingness* and __—, the material is not continuously triggering DPOAEs throughout the work, but it is important that the listener experiences that phenomenon in my works. *If; slowly* triggers DPOAEs more consistently but creates interesting rhythmic changes at different sections of the piece. The ideal outcomes of the works are for the audience to experience sound as a sculptural and an immersive entity, (through increased physical and spatial aspects), participate in creating their own sonic experience and be exposed to otoacoustic emissions in an artistic context. However, the immersive experience may come and go as the auditory distortions providing the physicality and hyper-awareness of space drift in and out due to the changing structure of the works.

All of the works in this section and the rest of the portfolio use the physical and spatial potential of DPOAEs and for this reason, are created purely for loudspeaker presentation. An ideal experience of the rest of the pieces in this project would include the audience member feeling surrounded by and immersed in sound that is simultaneously perceived as physically external and internal, relishing the agency they have in shaping what they hear and enjoying experimenting and exploring the effects movement in the space brings.

Nothingness

Figure 17 - The *Nothingness* sculptural instrument

Nothingness is an installation which comprises a stereo sound piece composed of processed sound recordings from playing a visual sculpture, and electronically synthesised sounds. The sculpture is placed in the center of a darkened room with a small light accentuating it while the sound piece is played on a loop through stereo speakers facing away from the corners of the space/room. The audience are invited to walk around the space and travel around the sculpture to gain a 360-degree perspective of the piece. While they are moving around the visual piece, their perception of the sonic piece will be also be changing and adjusting to their movement, meaning as their visual aspects slightly change, so will the auditory. After they have examined the sculpture, the audience can stay in the space to continue the sonic experience ideally until all of the piece is heard.

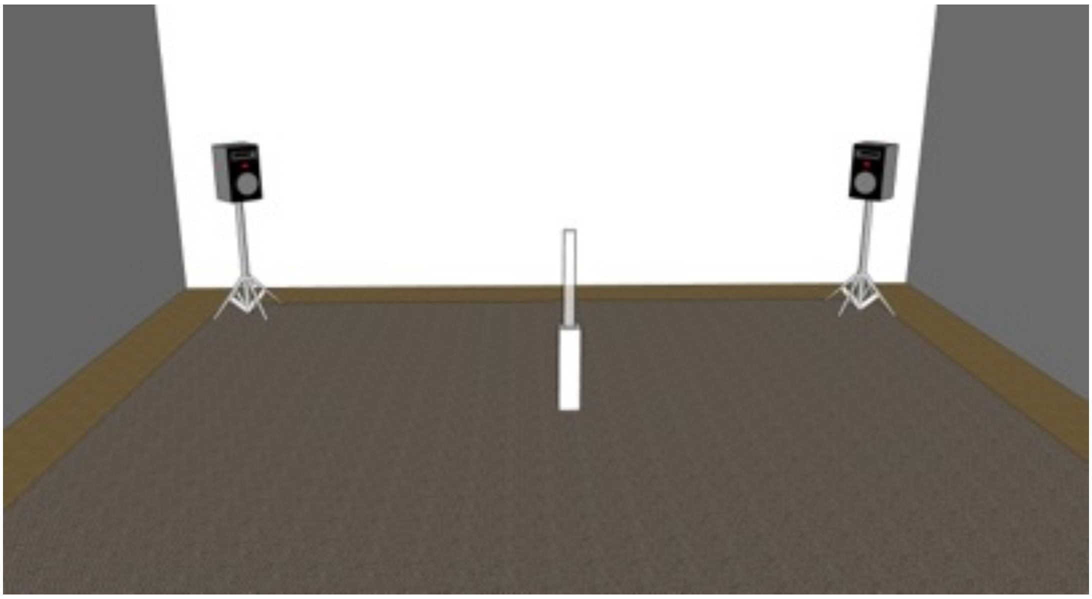


Figure 18 - *Nothingness* (Mock Installation Layout)

The sculpture was played by brushing and grinding various combs and brushes on the hardened bubble wrap which is set into the surface of the sculpture. These sounds were recorded via a condenser microphone and manipulated in real time using Ableton Live and a variety of Max for Live patches. The live recording was spliced into short phrases and blended with electronically synthesised sine waves made in Max. The sine tones are treated in the same way as non-pitched object sounds from the sculpture and no musical relevance is given to the frequency. The choice of frequency was decided by which best delivered the distortion product otoacoustic emissions (DPOAEs). The piece's compositional focus in on the gestural and rhythmic elements in each of the sections and the mix of timbre and texture between the processed sculpture recordings and the electronic sine waves.

In order to trigger otoacoustic emissions, the piece uses two pairs of sustained sine wave frequencies at a division of 1.2. The highest of each pair is panned completely to the left and the lower panned completely to the right. The DPOAEs this technique creates presents the effect of change when a listener moves their head, but the frequencies or note of the emission is not so apparent. However, at the middle section of the piece, there is fast changing rhythmic material, in which, for every pair of frequencies, there is the ratio of 1.2. Each pair offers a slightly different emission so, by changing so fast, they become much more obvious to the experienced or non-experienced listener alike. It is the act of changing the emission which equals the most obvious and intense experience.

__—

Figure 19 - __— (Installed at *INTIME* Conference at Coventry University)

__— is an installation piece which uses a sculpture made from steel sheets as well as a stereo sound art piece made from sound recordings of the metal materials along with electronically synthesised sine waves. The piece is presented in a similar way to *Nothingness* in which the sculpture is placed in a darkened room. The piece is looped, and the audience is invited to explore the space both visually and aurally.

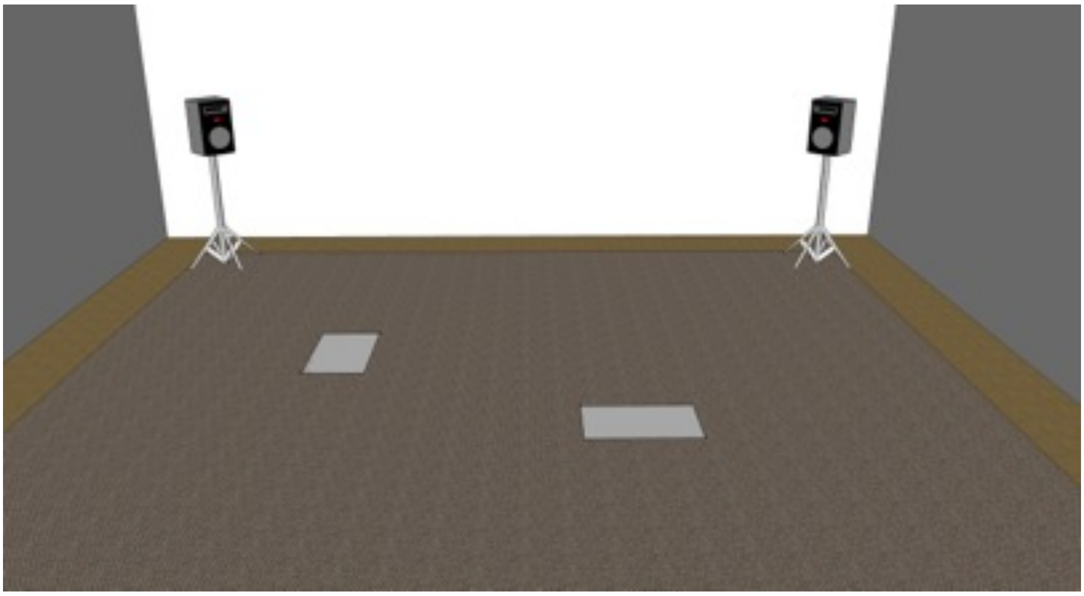


Figure 20 - __— (Mock Installation Layout)

A simple Max patch was devised at this stage to allow easy creation of the 1.2 ratio needed to trigger DPAOEs in the listener. The patch used frequency automation to create the sounds in the final section of the piece. By using this automation, the piece aimed to explore the sonic results of frequencies rising or falling while maintaining the important 1.2 ratio, and also the effect of this on the cochlea. This idea was used at different frequencies at a different duration in the final piece, descending from 2640hz to 2000hz in 0.9 seconds.

The end product delivers a very intense sensation of the emissions. This is due to other layers of the piece remaining at a static frequency and reacting with the movement of the other frequencies, creating aspects of distortion. The structure of the piece covers two specific ideas with transitions in between them. The piece uses DPOAEs in two ways, firstly to give the listener a stronger awareness of the space they are in, and secondly to allow the listener to distinctly feel the cochlea sensation. The piece aimed to guide the audience through an inner ear journey, with the first section for exploring and experiencing the space around them, and the second section receiving the physical sensation of DPOAEs in the space inside of the ear. The sensations move from feelings of space outside of the body to internalise into the head itself. The title of the piece attempts to be as abstract as possible by giving it no linguistic identity. This allows the audience to experience the piece with no preconceptions and gives them the ability to attach their own emotional or narrative concept to the work.

This work was exhibited at Coventry University as part of the INTIME Symposium in 2015. The testimonies from many of the people who experienced the installation referred to their interest and curiosity to otokinetic shaping and otoacoustic emissions generally. Many of the attendees were sound art/music academics or composers, and therefore, had some knowledge about OAEs, and were interested in using them in their works. However, there were a few people who remarked that they did not hear any special or extra auditory sensations from the work. It is for this reason that the style of works changed, from a narrative-based structure, which features otoacoustic emissions, to installations which have OAE stimulus continuously throughout.

If; slowly

Figure 21 - *If; slowly* sculptural instrument

If; slowly is an installation piece involving visual physical sculpture and coinciding sound work. The visual sculptural work is constructed of six metal tubes, which stand vertically at three different heights. The tubes are placed in a triangular formation and the audience is invited to explore the space around and in between each individual object. The stereo sound piece originates from speakers which are hidden from view.

The function of the steel objects is to define the space, giving the audience a sense of physicality and a visual entity to engage and interact with. These objects activate the space in the installation venue as sculptural material and highlight the space in-between two poles. The audience experiencing the work is guided by these physical anchors and the space between becomes more tangible. The steel objects also have a sonic function in the work. Apart from the low frequency sine tones and articulated noise, all of the sounds in the composition are processed recordings of the tubes being struck. In a search to create the most effective sustained tone, the objects were recorded being struck with various materials. It was decided that the best material and item to use as a beater was a large wooden panel. The playing technique involved balancing the tubes near the centre, allowing them to move and vibrate freely.

In the previous project work up to this stage, sine waves were used in addition to object sounds as a method of triggering DPOAEs. *If; slowly* is unique in that it is the sculptural objects from which the auditory triggering stimulus originates. To do this, the successful sustained tones from striking the tubes were stretched using *Logic Pro X's Flexitime*. This method of processing was chosen because it is imperfect, and often creates inconsistencies in the sound. The use of frequency inconsistencies create interesting rhythmic elements in the stretched material, which creates rhythmic patterns of DPOAEs which would not occur in 'perfect' electronic wave forms. These sounds were then processed using a Max patch made for this project.

This patch takes any inputted sound file and gives me the option to create four different pitched instances of the sound which are layered. These four pitch shifters are numbered in roman numerals on the patch. There is also a master pitch control, which can be used to alter the pitch of all the other pitch shifters, or utilised alone if just one instance needs to be created.

The structure of the sound piece is made of two key sections. These sections are broken up by transitions which act as ways to refocus the audience. When listening for extending periods of time to one stream of drone-like sounds triggering DPOAEs, the effect can become normalised in the listener's perception; therefore, these interruptions and change of frequencies, aim to re-engage the audience and restart the physical and spatial experience.

This work, although not exhibited at a public event or gallery, was shown to a variety of people such as fellow PhD students during a colloquium presentation. Much of the feedback was focused on the minimalist style of the work. However, there was also a general consensus that the use of otoacoustic emissions added physicality to the work, and otokinetic shaping added a level of participation in a way no-one had experienced before.

Sound Sculpture

The rest of the works in the portfolio are purposely reductive and minimal in their approach. This is to give the audience/listener more control over their experience of the work. The pieces feature no real narrative or structure, other than perhaps their repetition. The indefinite repetition and continuous consistency of the sound is used to give the impression that the sound is solid like a physical object, which is an attempt to obscure the temporality of sound. The duration and structure in the works are to be discovered and controlled by the audience/listener, and the sound of the work is controlled by otokinetic shaping.

Static, *Shift*, *Seesaw* and *Forms & Perspectives* use no visual or physical sculptural objects and invest fully in the notion that the sound itself is the sculpture. As a result of this, the audience also have the choice to imagine a possible visual element if they so wish.

Due to a similar aesthetic, *Static*, *Shift* and *Seesaw* can fuse together as a triptych, if exhibited in the right multi-space situation. The three works would need to have their own separate space but can benefit from being experienced one after another.

The ideal setting and conditions for these pieces are those of a typical white cube gallery. The space should be empty to allow the audience to move around freely and to remove any distracting visual stimuli. The sound system for these installation pieces needs to have the amplitude to provide the needed volume for the work for the space, i.e. more volume for a larger space to ensure the emissions are effective. The lighting in the space needs to be minimal so does not cause a visual distraction. The only visual elements in the space should be the loudspeakers, which ideally would be embedded into the wall(s) of the space to minimise their physical presentation. These elements are important to devoid the space of other physical or visual aspects of a space that will remove the physical focus on the sound and the experience of its sculpture presence.

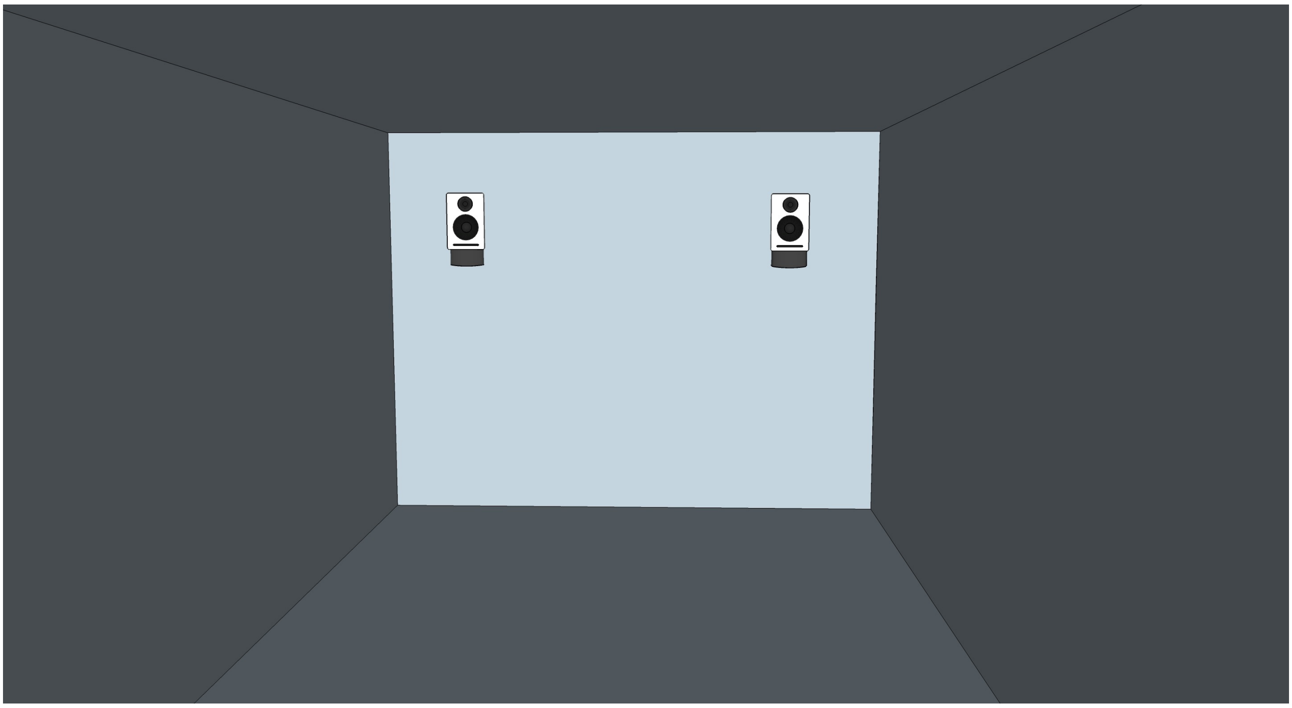


Figure 22 - Mock layout for sound sculpture installations

There is also the aesthetic choice for the works in this section and 'Digital Visual Sculpture' to be presented at high volume. The logic behind this choice is two-fold. Firstly, this is so the emissions are at their most apparent. Although the emissions can be heard at mid-level volumes, at higher levels the sensations of the emissions become more physical rather than exclusively sonic, which is essential as the physical element of the sensation is the reason for using them. With this physical effect, they become more intense and therefore more apparent meaning they will be obvious even to an uneducated or untrained listener. The second reason links with the definition used in this project for immersion. It is the aim of these works for the audience to be immersed in sound that fills the room. The experience should be overwhelming and overpower the auditory sense. The works should also be immersive in the way the sound intensely commands control of the space, turning every audience's members movement into a noticeable auditory experience for them. Due to this fact, it is also to be expected that some people may find the experience of the pieces uncomfortable or even distressing, in which case they are free to leave.

Static

Static is a concept piece. It is realised through using the *Static* patch constructed in Max. The work is a sound installation for two or four speakers, presenting four undefined static frequencies in an undefined space. *Static* was the first piece created in the project in which there was no visual accompaniment. This is because, at this point, it was decided sound could function and achieve a sculptural identity itself with no reliance on visual physical objects. *Static* is an investigation of how simple and reductive a sound work can be but still remain equivalent to sculpture. This installation is a proof of concept.

One of the biggest advantages of using otoacoustic emissions as a method of creating space and physicality, is that they can be triggered in any space and do not need to be tuned to set spatial dimensions. *Static* makes use of this portability but also has no fixed frequency set. The *Static* patch offers five predetermined frequency set variations, which offer particularly powerful DPOAEs. However, the user (usually the artist, but, the work can be installed remotely with the artist's guidance) is encouraged to select the random button, which will trigger a random frequency set. The focus of this piece is not on the composition of sonic material, as that can be completely random, but on the concept of exploring and interacting with space through auditory distortions. Once a frequency set is selected, it will remain static for the duration of the installation. This is what Joanna Demers refers to as stasis (Demers, 2010); however, and as with most of the works in this project, it is the listener that initiates the narrative experience by moving around the space and creating their own intimate composition from their navigational choices. The experience of the piece will be different in each presentation, not only because of the variable audio but because no two spaces will sound the same and it is incredibly unlikely two people will take the same route when exploring the space and creating their personal composition.

(not)Static is a modification built into the patch, which will trigger a new random frequency set at a chosen time interval. This element was created for situations in which the work is installed for a long period of time and therefore visitors may wish to experience the work more than once. This element provides the chance of the work being sonically different at each visit. The five variations which are pre-built in the patch were chosen to represent a wide range of frequencies and show the potential for intense physicality and immersion. They were created by intuitively tuning and playing with frequencies until the desired effect was achieved.

The process runs from box 1 to 3 to 2 and is constructed of two main calculations (box 1 and 2) with a calculation which joins them together (box 3). Firstly, a number between 800 and 1300 is randomly generated (left most orange floating number object in box 1). This number dictates the frequency in Hertz of the first sine tone (cycle~) and is key in the decision making of the frequency of the other three sine tones. The first frequency is divided by a randomly selected number between 1.05 - 1.15 (blue highlighted floating number object in box 1). This decides the second frequency (left orange floating number object in box 1). Box 3 works using the same process and calculation as box 1, however, the first frequency is decided by dividing the first frequency in box 1 by another randomly decided number between 1.05 - 1.15. This means, although there are two key sets of two frequencies, the two pairs are also related by an interval which triggers DPOAEs. This creates a more physical and intense sound. Another interesting feature of the patch is the frequencies being divided by a random triggered number, meaning nothing in the calculations is fixed. The number to be used in the division sum is set to a range of between 1.05 - 1.15. This is because although it is agreed the DPOAEs range is 1.1 to 1.3, this smaller range ensures that the stimulus will evoke a harsher texture and a more explicit physicality.

Shift

Shift is a work that grew out of experiments with some elements of the *Static* patch. It is also presented as a sound installation and is for either two or four speakers. The exploration was in pitch changes in one or two frequencies in an otherwise static set. This was examined earlier in one form in the work __—, however, in the experiments which became *Shift*, the focus was on a much slower ascending and descending pitch to investigate the effect this had on the otoacoustic emission's spatial and physical aspects. By slowly moving one of the frequencies, the listener can quite profoundly hear the change in interval relationships between the fixed frequencies and the rising or falling frequency. This relationship change includes hearing different rates of beating and interference patterns, but also different levels of physicality. There is also a dramatic change on which ear the physicality comes from due to different triggering relationships being formed. This gives the effect of otoacoustic emission panning.

The effect this has on the audience is somewhat collaborative. The changes in the sound one can create using otokinetic shaping, such as change of timbre or a sort of filtering, can sound quite similar to the sound of the changing frequency. This means that both the audience and the patch have the power to cause similar effects. The audience also has the power to shape the sound of the work while the patch is changing the frequency, which is where the work becomes particularly interesting.

The process the algorithm follows is a rise in frequency over ten seconds, remain at that for ten seconds, fall in frequencies over ten seconds, remain at that for ten seconds and loop infinitely. This is interesting because there is a level of indeterminacy programmed into the work. Three of the four frequencies are fixed and remain so for the duration of the installation. The moving frequency always descends to the same place, but there is a range of 100 frequencies it can choose in a set range. The work, therefore, will always sound slightly different as although the frequency rise and fall remain sounding relatively the same, the frequency relationships at the end of the ascension will be different and distinctive.

Seesaw

This work, similarly to *Shift*, was also born out of exploring different avenues of creativity using the *Static* patch. It can work for either two or four speakers. This installation examines how different frequencies, and therefore otoacoustic emissions, clash or accompany each other when played at the same time, and also whether this has a positive or negative effect on the intensity of the DPOAEs. In this work, the patch crossfades between two randomly generating frequency sets, allowing the audience to hear different relationships between the two sets and explore how different frequency intervals manifest in the inner ear. These frequencies are decided using a different calculation to that used in *Static.* Rather than using randomised numbers in all aspects of the formula, *Seesaw* uses fixed elements which were decided upon due to their reliability. The first frequency is generated in a range between 800 – 1600. This is then added to 75 to decide the second frequency. The number 75 creates a harmonic equality between the two frequencies but still manages to create an explicit auditory distortion.

To further the exploration of space and spatialisation in the works, this piece not only crossfades between different frequency sets, but also between the two speakers it is created for. This stereo movement adds another level of interest to the installation space the audience have to explore as they exploit the change in amplitude they will experience.

This work was presented at the Sound and Sculpture Conference 2016 at the University of Huddersfield, which was organised and hosted by the author. This conference involved composers, artists and researchers from five different countries presenting papers and exhibiting works surrounding the theme of sound and sculpture. Many of the attendees expressed positive comments and feedback regarding Seesaw, including the physicality of the otoacoustic emissions and the novel approach of otokinetic shaping, However, one person remarked the experience was 'painful' and left the installation very quickly.

Forms & Perspectives

Forms & Perspectives is a stereo or sixteen-channel sound-only installation and drone music composition that is based around the frequencies of 800 Hz and 666 Hz. This is because 800 Hz is one of the low frequencies that can still create intense DPOAEs effectively and 666 Hz has a profound physical effect on this and other frequencies used in tandem with 800. The physicality of emissions created from the range 700 Hz - 1000 Hz feels different to the sensation created from higher frequencies, for example 1600 Hz - 2000 Hz. The lower frequencies induce a stronger bodily sensation and feel more invasive.

The work functions as two frequency generators (800 Hz and 666 Hz) that play continuously and a collection of six specially curated sound files, which are triggered in a random order. The sound files are each pairs of two frequencies. These pairs were chosen because each one sits in a different frequency band of ten, i.e. 900, 1000, 1100, 1200. The frequencies chosen can be seen below (Figure 23). The sixteen-channel version of the work features, at maximum, eight loudspeakers functioning at once from the potential sixteen, meaning the sound sources keep moving. This adds a further spatial interplay to that already present through otokinetic shaping.

The patch is built in a way that it allows different frequency sets to overlap slightly. Due to this, this piece went through a range of different incarnations. In the first few attempts, there was purposely no planning in the frequency range of each sound file, thus many different very similar frequencies would clash. Although this may seem like a useful process in creating as much physicality as possible, DPOAEs can only be so complex before there is too much material being evoked and the sensation is lost. From these versions, it was deemed that choosing certain frequency ranges and a limit on exactly how much overlap is allowed was best for a successful work. Some of the closely related frequencies chosen (i.e. 960 and 950) may overlap, but because this is only allowed for a short period of time, this does not prove a problem for the work but more of an interesting inner ear experience. It is also useful to acknowledge that, according to my own experience, six is the maximum number of frequencies that can be used to trigger effective physical otoacoustic emissions. This is the reason why all of the pieces in this project use six or less, with four being the optimum number, especially when dealing with frequencies in close proximity.

Set	Freq 1 (Hz)	Freq 2 (Hz)
1	700	750
2	880	960
3	900	950
4	1000	1075
5	1100	1150
6	1200	1250

Figure 23 - Frequency sets used in *Forms & Perspectives*

This sound piece is different to that of the rest of the portfolio as it also functions as listening work rather than an installation experience exclusively. The notions behind creating this work as a drone piece was inspired by La Monte Young, particularly his work *Dream House* (1993). *Form & Perspectives* aims to explore the same meditative essence which creates an atmosphere for contemplation and perhaps spirituality, but with the physical and spatial aspects permitted through triggering DPOAEs that lie in the core of the project.

As mentioned at the start of this section of pieces, the ideal setting for the sound sculpture category of works is an empty white cube style contemporary art gallery. However, for this work, the space should involve some chairs dotted around the space. The number of chairs for sitting would depend on the size of the space and the number of people expected to attend the installation at one time. The notion of having seating is to encourage the audience to spend more time in the installation and be still momentarily to enjoy one particular sonic perspective before moving again.

Sound Sculpture / Digital Visual Sculpture

The next works in the portfolio fit both in the category of sound sculpture and digital visual sculpture. This is because they use otoacoustic emissions / otokinetic shaping fulfilling the criteria of sound sculpture but also include visuals that are provided by digital abstract video. Both examples of video media were created with a sculptural intent, either through the use of light or visual movement.

The ideal experience from these works would involve the audience member facing the video screen/projection, to be moving towards and away from the screen, and be moving their head from side to side to engage and create a personal interplay with the otoacoustic emissions. This would also involve them stopping at some points to explore the experience in their current location or to allow the sound and visual to change without their movement, making the piece more collaborative. Abandoning looking at the video at certain points is permitted as it is only an accompaniment to the audio and receiving the full sound experience is the focus of the installations.

Building on the immersive experience created in the sound sculpture sections of works, these pieces attempt to create further immersion by involving a visual modality too, while continuing the auditory, spatial and physical elements. Grau (2003) states that a multi-sensory experience leads to an increased sensation of immersion.

Shimmer

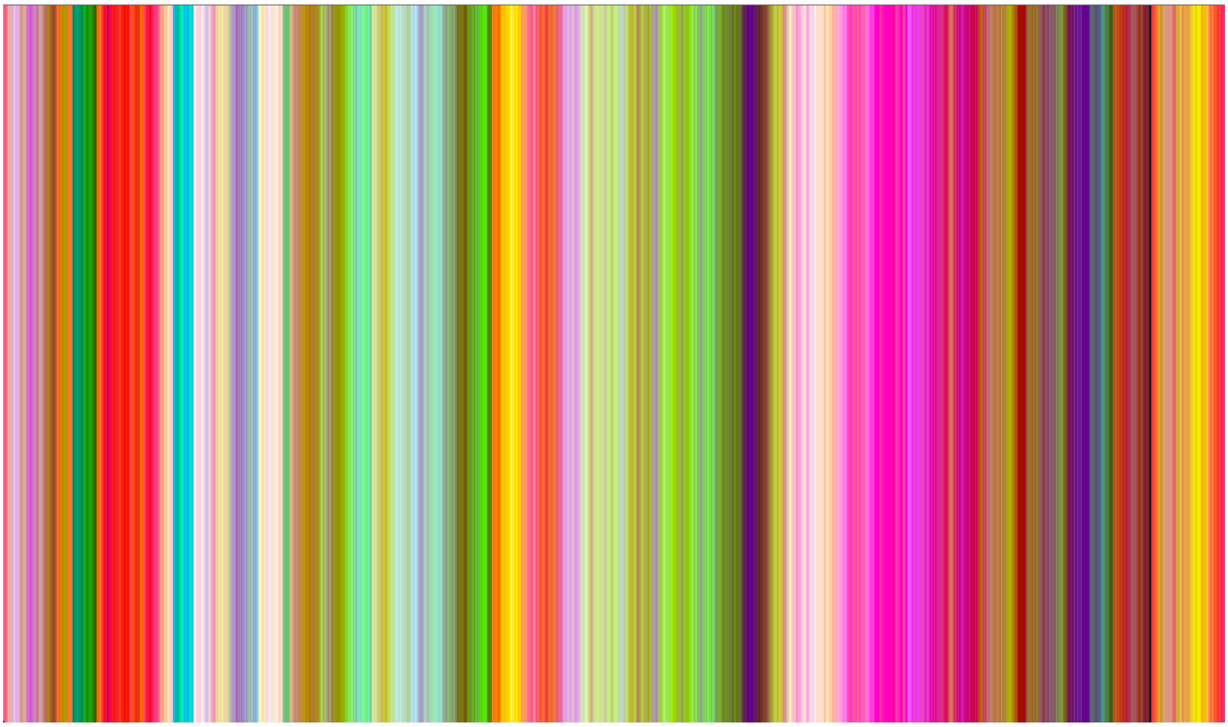


Figure 24 - A snapshot of *Shimmer* digital video

Shimmer is a minimalist installation work that combines electronic sound and video media. It is the first piece that explored digital or virtual imagery rather than something physical. The visual work is still intended to have a similarly physical and sculptural effect by being projected as large as possible on the walls of a dark installation space. The reason for this is so the video can become a light sculpture, affecting and activating the space in the installation in a similarly sculptural way to the sound work.

The function of the video is to echo the ‘shimmering’ effect of the sound piece in a visual domain. Aside from shimmering, the secondary theme in the work is balance. The sound piece explores the notion of balance in a space. It does this by different areas having different distribution or unequal elements due to the difference of pulsing rhythm in each of the four speakers. To match this, the video purposely travels in and out of synchrony with the audio, creating a further exploration of balance. The two mediums collaborate in this work to create an intense multi-sensory experience.

The four-channel sound piece in S*himmer* relies on very simple synthesis techniques to create four oscillating frequency units. The units used are called Macro Oscillators and are part of the *BEAP* set of pre-built patches in Max. The four oscillators are all pulsing at different speeds which creates the themed ‘shimmering’ but also creates an interesting mesh of rhythms. There is no change or evolution in the sound as like many of the works in this project, there is no interest in setting a narrative: that decision is for the audience to decide through their movement.

This is predominately a four-channel work, but can be reduced to stereo. In an installation setting, each oscillator is allocated an individual speaker and placed in a rectangle or square formation (Figure 25).

This relationship between space, different rhythms and sound reflections creates a woven mass of sound, in which different areas of the room feature different pockets of materials. The frequencies of the pulsing sounds are tuned in a manner which causes intense

DPOAEs, meaning the audience's agency achieved through otokinetic shaping is dramatically heightened as these sonic pockets can each be shaped and explored.

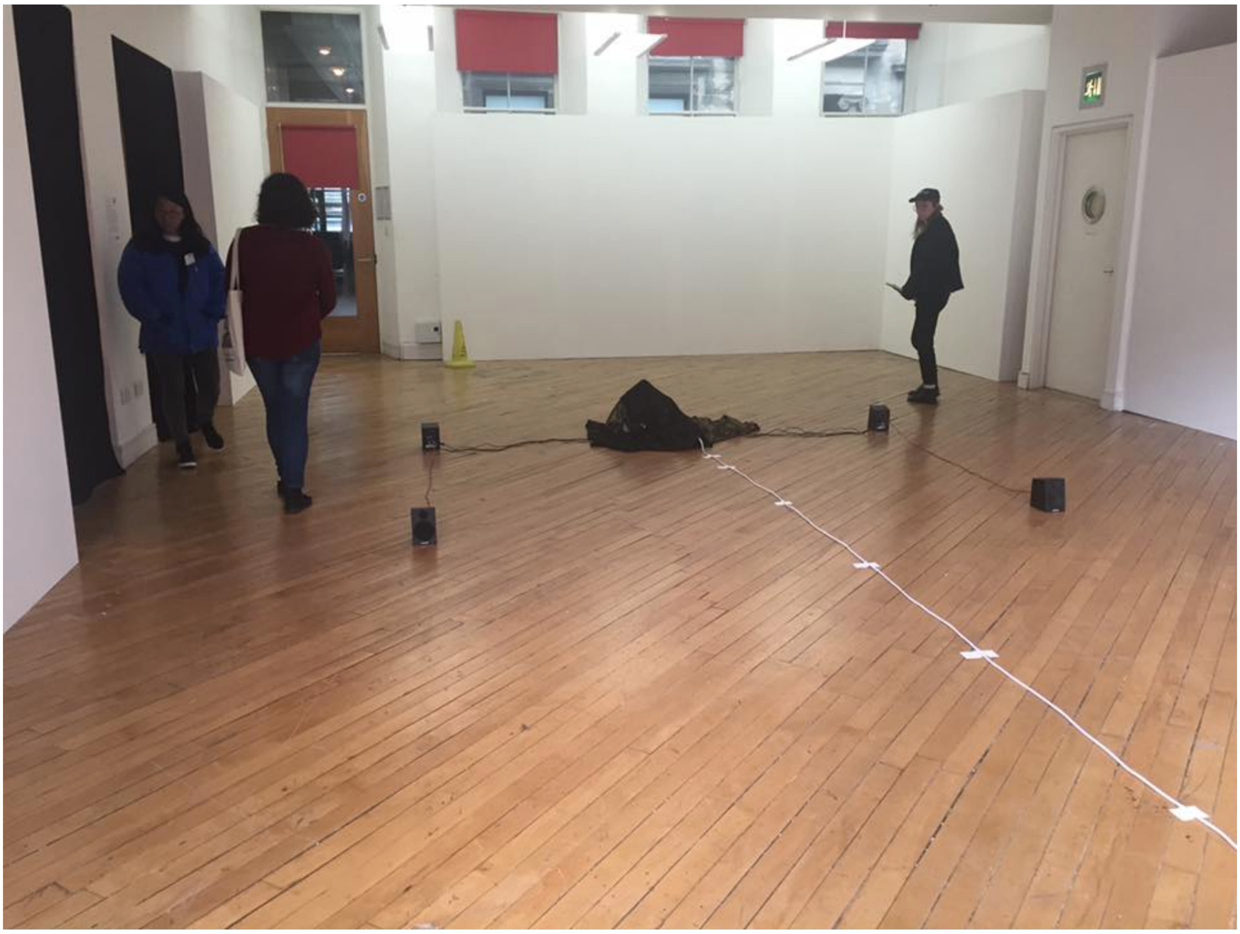


Figure 25 - *Shimmer* (without visual accompaniment) installed at *Sound Thought 2016,* Centre for Contemporary Arts, Glasgow

This work, (without visuals), was exhibited at the Centre for Contemporary Arts (CCA) in Glasgow, Scotland as part of Sound Thought, a festival organised by the University of Glasgow. This was a fruitful and interesting event at which to present the work because the gallery had advertised the event and it was open to the general public. This resulted in some of the installation audience not being sound researchers or academics involved in music. The usual attendees of many university-organised festivals or conferences would be researchers or academics. The verbal feedback I received regarding Shimmer was mostly very positive. A small group of people said they found the work 'too piercing' and 'uncomfortable'. There were also several instances of people walking into the installation and almost immediately leaving. However, a few people remained in the installation area for around thirty minutes, moving around every few minutes to examine the sound changes in different areas of the space.

Grow

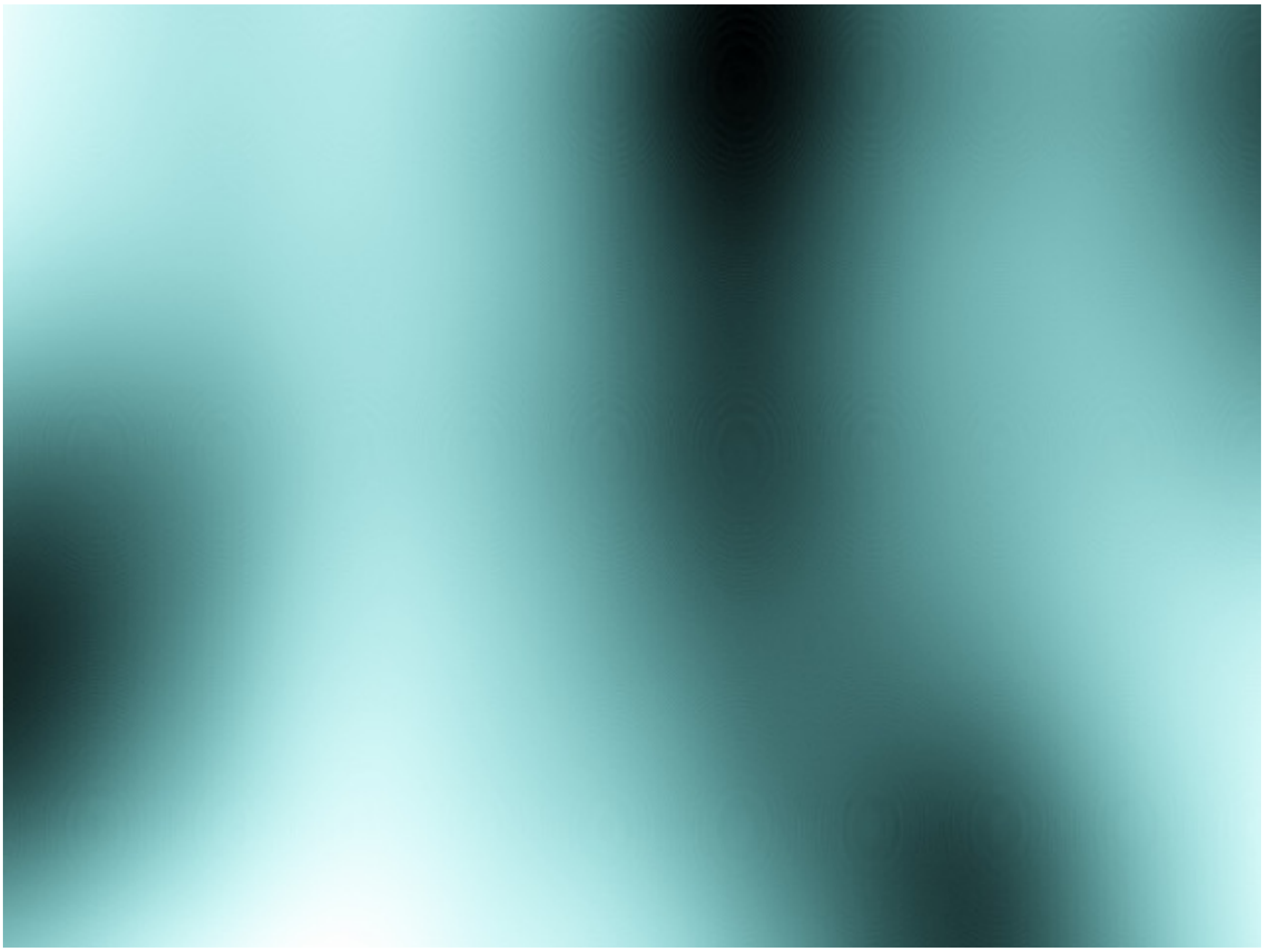


Figure 26 - *Grow* imagery example

Grow is an abstract multimedia installation work that combines algorithmically generated sound and imagery. The stereo sound piece explores how changes in amplitude affect the sensation of otoacoustic emissions. Each newly generated frequency set increases in volume when it is generated until it reaches the maximum level. Otoacoustic emissions rely on high volume to take full effect, so this amplitude process gives the audience the feeling of DPOAEs growing in their ears as the amplitude increases. Each new frequency is coincided by an abstract digital image.

There is no relation between the image and the frequency set or the effectiveness of its otoacoustic emission. The relationship lies through the concept of 'grow'. As the audience is presented with one of the images, the dark areas of the display seem to move and grow in size as the audience move their eyes around it. For this visual illusion to be effective, the presentation of the images should show on a fifty-inch television screen, rather than projected at wall size, as intended for *Shimmer.*

The images in the work are not generated in real-time as the sound material is, instead, the images were pre-generated using a different patch. This is due to the excessive computer power needed to generate the images, which makes it impractical to run in a live installation situation. The *Grow* patch accesses a folder of ninety eight images, which are called up and displayed when the sound process re-starts and a new frequency set is generated.

As one can see from the patch in the portfolio, rather than all of the numbers involved in the frequency calculation being created randomly, *Grow* uses a fixed formula. The initial frequency number, which is generated randomly, has defined numbers added to it (50, 250 and 300 respectively) to create the other frequencies in the set. This means, whereas other pieces use a division or a ratio approach, this piece does not; however, the otoacoustic emissions it creates are still powerful but can often sound similar for each new set.

The piece also plays with speed by changing the time the process takes to complete. This means that for every new frequency set and image that is generated, the length of the process, and therefore, the time before another pair is generated, descends by one second. After the cycle is completed, the patch then restarts at 20 seconds and repeats the cycle. This technique is used to play with different levels of growth in the otoacoustic emissions and acts as a way to re-engage the audience. Regardless of the speed of new generation, it is always advised that the audience travel-around the space slowly to fully appreciate the nuances in the sound from the use of the otokinetic shaping.

The work has currently not been exhibited as an installation and presently functions as a fixed media video. However, the piece was conceived to be an installation work and would be performed with the Max patch creating pseudo-random frequency sets and selecting from the pre-generated image collection.

Reflection

The initial research questions in this project concerned relationships between, and the creation of, minimalist visual art and sound art, particularly focusing on aspects of liveness and performance. As well as these considerations, my research explored the relationship between the audio and visual components of the installation works. The process of creation of the two mediums and the ways in which they inform each other is crucial to the understanding of the work. I, therefore, felt it imperative that I make all elements of the work to ensure this process was successful rather than collaborate with other artists. The research questions for the project at this time were:

- In what ways can visual art be compositional stimuli for sound performance?
- What are the relationships between the compositional and performative techniques in the creation of visual art and sound art?
- How can sculpture and sound art exist in one object?

The first two questions were addressed in the first work of the project, *Touch Tactile*. *Touch Tactile* experimented with the performative element of action painting used by Jackson Pollock, amongst others, and aimed to continue the same aspects of liveness in real-time sound generation, manipulation and processing. I believe this piece is a successful exploration of these intentions; however, the exploration that followed this failed. In an attempt to move the visual work into the three dimensional sculpture so it would mirror the three dimensional sound spatialisation I was interested in using, I found that the immediacy and directness I experienced with working with paint could not be imitated with physical objects. The second research question regarding the existence of multi-media art in one object resulted in the work, *Cuboid*. The *Cuboid* object comprises four steel sheets arranged to form the frame of a cuboid shape. As well as visual aspects, the steel sheets are played with percussion mallets and the sound is recorded and manipulated in a live sound art performance. This work successfully combines the two media into one aesthetic and functional object. However, this question intended to address how the relationship between the two mediums works in one object. In a performance of *Cuboid*, the visual element is ever-present but the sound art aspect is not. This is due to the temporal nature of sound and the fact that the *Cuboid* object does not self-generate sound and therefore relies on performance (physically playing it as a percussion instrument and manipulating the sound) to create the sound art element. Due to this, it would be incorrect to say sound art 'exists' in the *Cuboid* object in the same way its visual appearance does, as the question insinuates.

After this, the focus of the research changed, and the research questions for the rest of the project were as follows:

- How can sound become sculptural?
- How can sound become a physical or bodily experience in an extension of normal hearing through the human hearing system?
- How does sound as sculpture effect the listener’s experience of space?
- How can otoacoustic emissions give agency to the audience?

The way in which this project has utilised the phenomenon of otoacoustic emissions, and created otokinetic shaping, resulted in a practice or approach being devised which involved sculptural sound, a physical and bodily experience of space, and audience participation and agency. With the use of visual media in the portfolio, there is the possibility one may question the function or purpose the use of visual art has, and if it is needed, why it is not present in all of the works. In all of the works which include a visual element, the elements' purpose is to assist and accompany the sound in two ways. Firstly, to engage another sense, (sight), into the installation or performance experience. One of the strong beliefs in this project was that the more senses invoked in an experience, the more physical and psychological the experience of the work would be, leading to a heightened immersive experience. The notion of different senses (modes) interacting and integrating in the brain is well established in psychology and neuroscience research (Meyer and Wuerger, 2001; Vroomen and Gelder, 2000; Biocca, Kim and Choi, 2001). In an audiovisual study by Shams et al (2011), it was shown that not only does an increase of cross-modal sensory information aid the processing of that information, but the addition of another sensory mode also enhances uni-modal sensory processing. Secondly, the visual media function is to describe or assist aspects of the sound art or the experience to be gained from it. An example of this is in the work, *If; slowly*, as the visual and physical materials protrude from the ground, they act to mark out the space in which the audience should move around and explore. This also raises the awareness of the space the audience member is in, therefore activating the space as a material component of the work.

However, in retrospect, I do not think that this approach was not always successful. A pertinent example of this is in the work *Shimmer*, particularly considering that *Shimmer* has been shown successfully without the video element of the work. A key idea of *Shimmer* was to explore the balance of the installation space and disparities in the rhythm and auditory beating, which the visual element does not overtly illustrate. Secondly, the work being four-channel, encourages the audience to move in a wide range of directions, angles and speeds over the horizontal plane, often facing away from the video completely. It is for this reason, the later work, *Grow*, remains as a stereo work. The successfulness of visual media in the earlier piece, *Nothingness*, also comes into question. It fails to describe or assist any aspects of the sound work, or indeed add anything to the installation experience. However, it does expose the audience to the original source of manipulated sounds.

The change in the presentation of the works from a more narrative structure to a minimal looping theme/process was done in an effort to ensure the paramount purpose of the works was successful. The purpose, (excluding the works *Cuboid* and *Touch Tactile*), was to experience otoacoustic emissions and the new concept of otokinetic shaping. To ensure the audience experience otoacoustic emissions and otokinetic shaping, the later works, (*Static*, *Shift*, *Seesaw*, *Shimmer* and *Grow*), feature triggering stimuli throughout the duration of the installation. This is a reliable and guaranteed method to ensure they are experienced. For this reason, the works __ — and *Nothingness* have the possibility to be unsuccessful if people enter at a point at which the OAE stimulus is not present and it begins.

As expressed previously in various piece descriptions, a minority of audience members found the experience too uncomfortable to persist with it. An installation approach was chosen over a fixed-media presentation because, as well as allowing the audience movement, which is a core element of the aesthetic, the audience has the agency to leave when they wish without the social conventions which would exist in a live concert situation. This was a successful element of the practice that was greatly appreciated by some. For those that chose to stay for extended periods of time, the otoacoustic emissions facilitated an engrossing sonic exploration of the installation space.

Conclusion

Project Categories

Sculptural Tools

There are many examples of music and sound art which have been inspired by visual art and vice versa (Kennedy, 2007), however, a distinctive feature of this research was my choice to create both elements and so highlight structural and perceptual elements between them. In the case of the work *Touch Tactile*, the mediums share the same performative process and gestural quality, examining the link between performative elements of creating both media. In practice, anything can be used for inspiration for composition or mapped as musical information; however, the experimentation with the ideas of Manuella Blackburn's spectromorphology vocabulary, uses a previously established framework in a new and unique way, offering the idea of applying the spectromorphology's use of visual shapes to those of abstract sculpture. To gain full benefit in the future, the sculptural application of the vocabulary as a compositional tool would be better utilised in the hands of a gestural electroacoustic composer, or perhaps a sound artist that does not focus on such a minimalist approach as myself.

Sculptural Instruments

Artists such as Pierre Bastien create objects and devices with the purpose of creating sound art. Bastien's autonomous devices are designed so that the method by which they function is intrinsic to the visual appearance of the object. In comparison, the sculptures created in this research function as sound instruments in a way that is extrinsic to the visual design, and the sculptures are able to function as visual art and sound instruments independently. An intention of the research was to create an original multi-medium and multi-functional object involving contemporary sculptural practices and use as a sonic instrument. This was achieved in works *Cuboid*, *Nothingness* and *if; slowly*.

Sound Sculpture

A variety of original ideas were established in this category of works and research. This was where sound as sculpture using distortion product otoacoustic emissions became the focus of the research project. Through the use of the phenomenon, it was possible to create engulfing and immersive sound environments, building on the use of space explored in Serra and Flavin's encompassing sculptural works, and the physicality created in Ikeda and Amacher's sound art releases. By actively using otoacoustic emissions in the works, it has expanded its limited repertoire. However, the unique contribution is in the way it was used in the project, focusing on the effect of movement. The works that explicitly address movement create a shift of control from the artist to the audience, creating works which use the listener's physiological hearing system as a control device for them to build and construct their own sonic composition. This is a unique and unknown, or at best disregarded, application of DPOAEs, which highlights the potential that exists in exploring the phenomenon. This project coined the term ‘otokinetic shaping’ for this concept.

Digital Visual Sculpture

In this research and category of works, the intention was to achieve a different way to create with visuals, that still remained sculptural, but in the virtual domain. The visual aspects of the works in this category aim to represent movement rather than space and video media is ideal for this. Both works, *Grow* and *Shimmer*, aim to visually capture an element of the experience of moving in an environment in which otoacoustic emissions are being triggered. *Grow*, in particular, aims to mirror the agency the audience has within the sonic art by providing them with the same control of their experience through the use of illusionary visuals. *Grow* and *Shimmer* accomplished the intention to create video visuals that were equally as sculptural and physical as the sound work, creating minimalist audiovisual installations with an intense sense of immersion. These works join the novel element of otokinetic shaping and video art.

Future Research

This project has unearthed some topics which will form a basis for further future research. The notion of exploring similarities and dissimilarities of the techniques of creation in visual and sound art, has the potential to construct frameworks to create new and interesting works. As mentioned in previous sections, the notion of exploring spectromorphology icons, symbols and graphics as a method of sonifying three-dimensional sculpture, opens a new network between the two mediums that has not been previously explored. For example, a work could be completely based around a gesture 'read' from a three-dimensional sculpture. A second avenue, leading on from the ideas in *Touch Tactile*, could explore how sound could be manipulated in the same way that clay, wood and metal is in a sculptural process, and create some analogous aspects in the techniques used in the two mediums of the work.

There is also potential in using the definition of sound sculpture established in this research. This project utilised DPOAEs as a method of fulfilling the definition criteria. However, the definition may also be useful by seeking other ways to evoke senses of physicality and space using sound. An example of this could be through the use of low frequency sounds which are felt more than actually heard. An unused idea for a piece, which was intending to lead on from *Cuboid*, is the creation of a physical object interface that the audience touch or inhabit: the notion being that the audience receive the work through the tactility of resonance and vibration rather than through hearing. This interface could be used as an instrument to realise many different compositions from different composers, giving an audience a different way to experience sound.

By focussing on DPOAEs, there is much potential in using otoacoustic emissions in creative work, and still further exploration in the many ways the phenomenon can be used. This project has created and demonstrated a novel way in which to interact with otoacoustic emissions through the use of space and movement. There is clearly the potential to extend this approach much further in a combination of directions: firstly, using methods such as the spatialisation practice of electroacoustic music in tandem with otokinetic shaping. This means the sound could be moving and changing as well as giving the audience the agency to move and change it themselves. The movement between different speakers could be controlled by computer algorithm thus remaining in line with my ideas of my role as the artist. Secondly, works could feature sound stimuli, which both trigger otoacoustic emissions and are tuned to an installation space in the vein of Michael Brewster's sound sculpture works. This could extend the already immersive and bodily physicality of the sensation of the emissions, but also allow for the room's resonance to be explored by the audience. The portfolio works already feature a subtle change of frequencies throughout different areas of an installation space, but by using the space's resonance, this phenomenon can be transformed into a more sophisticated and extensive experience.

Another important topic this project examined was minimalist art. The pieces later in the project, *Static*, *Seesaw* and *Shift*, involve a single idea which is repeated indefinitely to create the work. This creates a static-like sonic entity or object. An interesting area to pursue would be to create a visual version of this. This could be a looping minimal shape-based animation, forming a visual digital object. This would then create a digital platform to play with the relationship between the visual and the aural. It could also be the beginning of the creation of an audiovisual language, in which different lines or geometric shapes equate to different sounds. This could eventually lead on to an interactive system in which any shape could be drawn and animated, and then sonified.

Bibliography / Discography / Webography

Adkins, M. (2007). The Influence of Futurist painting in my music. *In Digital Music Research Network (DMRN) Summer Conference, Leeds Metropolitan University*. Retrieved from http://eprints.hud.ac.uk/4272/. (Accessed 14 March 2017)

Anfam, D. (n.d.). Action painting. *Grove Art Online. Oxford Art Online.* Retrieved from http://www.oxfordartonline.com.libaccess.hud.ac.uk/subscriber/article/grove/art/T000382. (Accessed 14 March 2017)

Ankersmit, T. (2014). *Otolith (live at CTM Festival)*. Retrieved from https://soundcloud.com/weerzin/live-at-ctm-2015-excerpt. (Accessed 14 March 2017)

Amacher, Maryanne. (1999). *Sound Characters: Making the Third Ear*, Tzadik TZ 7043

Barrett, N. (2016). A 3-D Future for Loudspeaker Orchestras Emulated in Higher-Order Ambisonics. In *International Computer Music Conference Netherlands.* Retrieved from http://www.icmc2016.com/program/PaperTrack/s52.html. (Accessed 14 March 2017)

Balkany T.J., Zeitler D.M. (2013) Duplex Theory of Sound Localization. In: *Kountakis S.E. (eds) Encyclopedia of Otolaryngology, Head and Neck Surgery*. Springer, Berlin, Heidelberg

Basanta, A [Adam Basanta]. (2015). *A Room Listening to Itself*. [Video file] Retrieved from https://vimeo.com/135961039. (Accessed 14 March 2017)

Bernier, N. (n.d.). *Selected Performances and Installation*s. Retrieved from http://www.nicolasbernier.com/page/works.htm. (Accessed 14 March 2017)

Biocca, F., Kim, J. and Choi, Y. (2001). Visual Touch in Virtual Environments: An Exploratory Study of Presence, Multimodal Interfaces, and Cross-Modal Sensory Illusions. *Presence: Teleoperators and Virtual Environments*, 10(3), pp.247-265.

Bishop, C. (2005). *Installation art*. London: Tate Publ, p.14.

Biró, D.P. (1998). *Slowly Watching Memory: An analysis of Morton Feldman's "Rothko Chapel"* (Masters Thesis). Frankfurt University of Music and Performing Arts, Frankfurt.

Blackburn, M. (2009). Composing from spectromorphological vocabulary: proposed application, pedagogy and metadata. In *Electronic Music Studies Conference 09 (EMS),* *Buenos Aires*. Retrieved from http://www.ems-network.org/ems09/papers/blackburn.pdf. (Accessed 15 March 2017)

Brewster, M. (n.d.). *Artist Profile*. [available online] Retrieved from http://www.michaelbrewsterart.com/pages/artist-profile-michael-brewster-american-sculptor (Accessed 14 March 2017)

Brien, J. & Important Records, . (n.d.). *Bertoia Sculptures*. [Photograph]. Retrieved from http://www.npr.org/2016/03/26/468881945/sound-sculptor-harry-bertoia-created-musical-meditative-art. (Accessed 14 March 2017)

Bright Eye Cinema. (2012). *Nam June Paik "Participation TV"* [Video file]. Retrieved from https://vimeo.com/49988167 (Accessed 14 March 2017)

Celant, G. (2014). *Art or Sound*. Fondazione Prada: Milan

Crisscrossing. (2007). *Pollock painting (1950)* [Video file]. Retrieved from https://www.youtube.com/watch?v=7bICqvmKL5s (Accessed 14 March 2017)

Chechile, A. (2016). The Ear Tone Toolbox for Auditory Distortion Product Synthesis. In *International Computer Music Conference* Netherlands, Retrieved from http://www.icmc2016.com/program/PaperTrack/s149.html. (Accessed 14 March 2017)

Chittka, L. & Brockmann, A. (2009). *A diagram of the anatomy of the human ear*. [Diagram]. Retrieved from https://commons.wikimedia.org/wiki/File%3AAnatomy_of_the_Human_Ear_en.svg. (Accessed 14 March 2017)

Clarke, M., Dufeu, F., & Manning, P. (2014). Barry Truax Riverrun (1986/2004), a case study from the TaCEM project, exploring new approaches to techniques of analysis and re-synthesis in the study of concert electroacoustic works. *Proceedings of the Electroacoustic Music Studies Network Conference*. Retrieved from http://www.ems-network.org/IMG/pdf_ems14_clarke_dufeu_manning.pdf. (Accessed 14 March 2017)

Cummings, S. (Producer / Host). (2017, April 18). *The Dialogues: Monty Adkins* [Audio Podcast]. Retrieved from http://5against4.com/2017/04/18/the-dialogues-monty-adkins/. (Accessed 20 April 2017)

Demers, J. (2010). *Listening through the noise: the aesthetics of experimental electronic noise*. Oxford University Press: Oxford

Discogs. (n.d.). *Bertoia* – Sonambient (Complete Collection)*. Retrieved from https://www.discogs.com/Bertoia-Sonambient-Complete-Collection/release/8128125. (Accessed 14 March 2017)

Dyson, F. (2009). *Sounding new media*. Berkeley, Calif: University of California Press.

Eimert, H. & Stockhausen, K. (1958). *Die Reihe 1: Electronic Music*. Pennsylvania: Theodore Presser Company

Evans, K. (Director). (1987). *Jackson Pollock*. [DVD]. United Kingdom: Image Entertainment.

Freeman, J. (n.d.). *FLOCK: for saxophone quartet, video, electronic sound, dancers, and audience participation*. Retrieved from http://distributedmusic.gatech.edu/flock. (Accessed 14 March 2017)

Gabo, N. (2014). *Sculpting the Line: British Sculptors as Printmakers.* [Exhibition catalogue] Exhibited at the Hepworth Wakefield, 20 September 2014 - 6 September 2015.

Gimenes, M., Largeron, P., & Miranda, E.R. (2016). Frontiers: Expanding Musical Imagination With Audience Participation. *NIME 2016 Proceedings*. Retrieved from http://www.nime.org/proceedings/2016/nime2016_paper0068.pdf. (Accessed 14 March 2017)

Gottschalk, J. (2016). Experimental music since 1970. New York: Bloomsbury Academic, an imprint of Bloomsbury Publishing, pp.110-116.

Grau, O. (2003). *Virtual art: From Illusion to Immersion*. Cambridge, Mass.: MIT Press.

Ha, B. (2015). A Pioneer of Interactive Art: Nam June Paik as Musique Concrète Composing Researcher. *Proceedings of the 21st International Symposium on Electronic Art*. (Sessions 38).

Hall III , J.W. & Dhar, S. (2009). *Otoacoustic Emmissions: Principles, Procedures and Protocols*. San Diego, CA: Plural Publishing.

Harrison, J. (1998). Sound, space, sculpture: some thoughts on the "what", "how" and "why" of sound diffusion. *Organised Sound,* 3(2), 117–127. Retrieved from https://www.cambridge.org/core/journals/organised-sound/article/sound-space-sculpture-some-thoughts-on-the-what-how-and-why-of-sound-diffusion/6D572DED6F15EE41FF81F339AE23BCAC (Accessed 14 March 2017)

Hartmann, W., Rakerd, B., Crawford, Z. and Zhang, P. (2016). Transaural experiments and a revised duplex theory for the localization of low-frequency tones. *The Journal of the Acoustical Society of America*, 139(2), pp.968-985.

Horseman, Samantha Marie. (2012). *Dynamic Relationships between the Sonic Artist, the Sonic Artwork and its Audience: an Investigation through Theoretically Informed Creative Practice* (Doctoral thesis). Retrieved from http://eprints.hud.ac.uk/18077. (Accessed 14 March 2017)

Hickey, B. & Robertson, O. (n.d.). *The Rothko Chapel*. [Photograph]. Retrieved from http://www.npr.org/2011/03/01/134160717/meditation-and-modern-art-meet-in-rothko-chapel. (Accessed 14 March 2017)

Ikeda, R. (2009). *Dataplex* [CD]. Germany: Raster Noton.

Ikeda, R. (1999). *Mort Aux Vaches* [CD]. Netherlands: Mort Aux Vaches.

Ikeda, R. (2013). *Supercodex* [CD]. Germany: Raster Noton.

Ikeda, R. (2008). *Test Patterns* [CD]. Germany: Raster Noton.

Important Records [Importantrecords]. (2015, Nov 17). *Harry Bertoia Sonambient Sculpture Barn Motion Study* [Video file]. Retrieved from https://youtu.be/zS-YQ0-Rmmk (Accessed 14 March 2017)

IRCAM. (n.d.). *The Rothko Chapel* (1971). Retrieved from http://brahms.ircam.fr/works/work/8558/l. (Accessed 14 March 2017)

Jensen, M.G. (2009). John Cage, Chance Operations, and the Chaos Game: Cage and the "I Ching". *The Musical Times*, 150 (1907), 97-102. Retrieved from http://www.jstor.org/stable/25597623. (Accessed 14 March 2017)

John Wynne. (2016). *Air I Breathe: Sound and Space seminar at Gazelli Art House* [video file] Available at https://vimeo.com/155808077 (Accessed 14 March 2017)

Kemp, D. (2002). Otoacoustic emissions, their origin in cochlear function, and use. *British Medical Bulletin*, 63 (1), 223-241. doi: 10.1093/bmb/63.1.223.

Kemp, D. (1978). Stimulated acoustic emissions from within the human auditory system. *The Journal of the Acoustical Society of America*, 64 (5), 1386-1391. doi: 10.1121/1.382104.

Kirkegaard, J. (n.d.). *EUSTACHIA - for 20 Voices*. Retrieved from http://fonik.dk/works/stereocilia7.html. (Accessed 14 March 2017)

Kirkegaard, J. (n.d.). *STEREOCILIA - for 7 Ears*. Retrieved from http://fonik.dk/works/stereocilia7.html. (Accessed 14 March 2017)

Kendall, G.S., Haworth, C., & Cadiz, R.F. (2014). Sound Synthesis with Auditory Distortion Products. *Computer Music Journal*. 38 (4), 5-23.

Kennedy, S.L. (2007). *Painting Music: Rhythm And Movement.* Art Sheldon Memorial Art Gallery, University of Nebraska- Lincoln, Nebraska. (Accessed 28 March 2017).

Kirk, J. (2010). Otoacoustic emissions as a compositional tool. *In Proceedings of the 2010 International Computer Music Conference*. Paper presented at the State University of New York, Stony Brook, New York, 1-5 June. Ann Arbor, MI: University of Michigan.

Kursell, J. (2015). *A Third Note: Helmholtz, Palestrina, and the Early History of Musicology*. Isis, 106 (2), 353-366. doi: 10.1086/682003.

LA Artstream (2014). *Ear Meal with Michael Brewster* [video file] Retrieved from https://vimeo.com/107233761 (Accessed 14 March 2017)

LaBelle, B. (2006). Background Noise: Perspectives on Sound Art. Chapter 11. Continuum: New York

Lietner, B. (n.d.). Work List. Retrieved from http://www.bernhardleitner.at/works. (Accessed 14 March 2017)

Lohri, A., Carral, S., & Chatziioannou, V. (2012). Combination Tones in Violins. *Archives of Acoustics*, 36 (4), 727-740. doi: 10.2478/v10168-011-0049-1.

Luque, S. (2011). Stochastic synthesis: An overview. *Proceedings of the Xenakis International Symposium*. Retrieved from https://www.gold.ac.uk/media/documents-by-section/departments/music/09.2-Sergio-Luque.pdf (Accessed 14 March 2017)

Martin, E.A. (2015). *Concise Medical Dictionary* (9th ed.). Oxford: Oxford University Press.

Museum of Modern Art. (n.d.). *Marina Abramović and ULAY. Rest Energy. 1980*. Retrieved from https://www.moma.org/explore/multimedia/audios/190/1976. (Accessed 14 March 2017)

Museum of Modern Art. (2007). *Richard Serra | Intersection II (1992)*. [Video file] Retrieved from https://www.youtube.com/watch?v=C_OmWlMjsxQ. (Accessed 14 March 2017)

NA9223. (2011) *Naum Gabo & Noton Pevsner - The Realistic Manifesto (Manifesto Extract, 1920)*. [video file] Retrieved from https://www.youtube.com/watch?v=2k-JGuhyqKE (Accessed 14 March 2017)

Nakamura, J. and Csikszentmihalyi, M. (2009). Flow theory and research. In: S. Lopez and C. Snyder, ed., *The Oxford Handbook of Positive Psychology*, 2nd ed. New York: Oxford Press, pp.195-206.

National Gallery of Art. (2004) *Dan Flavin: A retrospective*. [online] Available at https://www.nga.gov/exhibitions/2004/flavin/light/light_p2.shtm (Accessed 14 March 2017)

Ouzounian, G. (2006). Embodied Sound: Aural Architectures and the Body. Contemporary Music Review, vol 25, no. 1-2, pp. 69-79.

Perkis, T. (2003). Complexity and Emergence in the American Experimental Music Tradition. In J. Casti & A. Karlqvist (Eds.) *Art and Complexity* (pp. 75-84). Netherlands: Elsevier.

Potter, K. (2005). Hugh Davies: Iconoclastic innovator in electronic music. [available online] Available at http://www.independent.co.uk/news/obituaries/hugh-davies-18090.html (Accessed 14 March 2017)

Seo, J. (2015). Aesthetics of Immersion in Interactive Immersive Installation : Phenomenological Case Study. Proceedings of the 21st International Symposium on Electronic Art. [online] Available at:

http://isea2015.org/proceeding/submissions/ISEA2015_submission_237.pdf [Accessed 12 Sep. 2018].

Shams, L., Wozny, D., Kim, R. and Seitz, A. (2011). Influences of Multisensory Experience on Subsequent Unisensory Processing. *Frontiers in Psychology*, 2.

Smalley, D. (1997). Spectromorphology: explaining sound-shapes. *Organised Sound, 2* (2), 107-126. doi: 10.1017/S1355771897009059. (Accessed 14 March 2017)

Somló, D. (n.d.). *Mandala*. Retrieved from http://davidsomlo.com/mandala (Accessed 14 March 2017)

Steib, M. (1999). *Reader's Guide to Music: History, Theory and Criticism*. New York: Routledge.

Stevens, S. and Newman, E. (1936). The Localization of Actual Sources of Sound. *The American Journal of Psychology*, 48(2), p.297.

Strutt J. W. (1907). "On our perception of sound direction," *Philos. Mag*. 13, 214–232.10.1080/14786440709463595

Tate. (n.d.). *Marina Abramovic: Rhythm 0: 1974*. Retrieved from http://www.tate.org.uk/art/artworks/abramovic-rhythm-0-l03651. (Accessed 14 March 2017)

Tate. (n.d.). *Number 23, Jackson Pollock*. [Photograph]. Retrieved from http://www.tate.org.uk/art/artworks/pollock-number-23-t00384. (Accessed 14 March 2017)

Tipei, S. (n.d.). *Indeterminacy*. Retrieved from http://ems.music.illinois.edu/courses/tipei/M202/Notes/cage1.html. (Accessed 14 March 2017)

Treves, T. (2000). *Model for 'Rotating Fountain': Summary*. [available online] Available at http://www.tate.org.uk/art/artworks/gabo-model-for-rotating-fountain-t06974/text-summary (Accessed 5 December 2016) (Accessed 14 March 2017)

Rakerd, B. and Hartmann, W. (1986). Localization of sound in rooms, III: Onset and duration effects. *The Journal of the Acoustical Society of America*, 80(6), pp.1695-1706.

Randel, D.M. (2003). *The Harvard Dictionary of Music (4th ed.)*. Cambridge, MA: Belknap Press of Harvard University Press.

Rothko Chapel. (n.d.). *About*. Retrieved from http://rothkochapel.org/learn/about/. (Accessed 14 March 2017)

Vroomen, J. and Gelder, B. (2000). Sound enhances visual perception: Cross-modal effects of auditory organization on vision. *Journal of Experimental Psychology: Human Perception and Performance*, 26(5), pp.1583-1590.

Wilhelm, R. (2011). *Introduction by Richard Wilhelm*. Retrieved from http://www.iging.com/intro/introduc.htm. (Accessed 14 March 2017)

Wong, M. (2013). *Sound sculpture*. Grove Music Online - The Grove Dictionary of American Music, (2) doi: e-ISBN: 9781561592630. (Accessed 14 March 2017)

Wuerger, S., Hofbauer, M. and Meyer, G. (2003). The integration of auditory and visual motion signals at threshold. *Perception & Psychophysics*, 65(8), pp.1188-1196.

Xenakis, I. (1992). *Formalized Music: Thought and Mathematics in Composition* (3rd ed.). New York: Pendragon Press.

Zurich University of the Arts. (n.d). *Karlheinz Stockhausen: Oktophonie*. Retrieved from http://ppeam.zhdk.ch/song/oktophonie/. (Accessed 14 March 2017)

Appendix A

List of output from this project

Publications

- Title: *A Dialogue Between the Seen and the Heard: The Live Use of Sound as a Sculptural Material and Sculpture as a Sound Instrument in Cuboid*
  Publisher: eContact (Canadian Electroacoustic Community) Date: April 2016

Performances / Exhibitions

- Sound and Sculpture Conference (SSC) - University of Huddersfield, UK - May 28th, 2016
  Work: Seesaw

- Sound Thought 2016 - Centre for Contemporary Arts / Glasgow University - March 30th, 2016
  Work: *Shimmer* (sound only).

- INTIME 2015 - Coventry University - October 24th, 2015
  Work: __—

- Electric Spring Festival 2015 - University of Huddersfield - February, 2015
  Work: *Cuboid*

Conference Paper Presentations

- Sound and Sculpture Conference (SSC) - University of Huddersfield, UK - May 28th - 29th, 2016
  Paper title: Sound as a Sculptural Substance & The Avoidance of Musicality in My Latest Work

- INTIME 2015 - Coventry University, UK - October 24th, 2015
  Paper title: The Use of Distortion Product Otoacoustic Emissions in '__—'

- The Toronto International Electroacoustic Symposium 2015 - Toronto, Canada - August 20th, 2015
  Paper title: A Dialogue Between the Seen and the Heard: The Live Use of Sound as a Sculptural Material and Sculpture as a Sound Instrument in Cuboid

- Sound Space Play 2015 - University of Leeds, UK - May 30th, 2015!
  Paper title: Space in Visual Art and Sound Art!

Conference Organisation

- Sound and Sculpture Conference (SSC) - University of Huddersfield, UK - May 28th, 2016
  Role: Principal organiser and host