# SOUND ART: SPACE, TIME & JOHANNESBURG


## BY: B.J. ENGELBRECHT

0216082A

Supervised by: Prof Gerrit Olivier


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# DECLARATION

I declare that this dissertation is my own unaided work. It is submitted for the degree of *Doctor of Philosophy* in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any other degree or examination in any other university.

*Barend Jacobus Engelbrecht*
(Name of Candidate)

11 / 01 / 21
(Date)

(Signature)

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# ABSTRACT

This thesis begins with a chronological overview of sound and aurality. It focuses quite strongly on music and on how elements key to the emergence of sound art are present in the history of music. Some of the key themes are: space as a composed element in music, the use of non-musical sound and sound recording and playback. This is followed by a discussion of the emergence of sound art in the latter half of the 20$^{th}$ century and a critique of the definition of sound art based on Tierry de Duve's aesthetics. Thereafter, the thesis provides a detailed look at the physical properties of sound and the biological mechanisms of hearing. Here, particular attention is paid to air and how a variety of physical and biological variables influence our perception of sound. The underlying theoretical claim is that one of the functions of sound art is to place the ordinariness of sound in context where a new awareness is created by 'making it strange' – sound art consciously connects us to our perception of the environment, time and particularly the 'becoming' of the present. Thus, the chapter that follows attends specifically to notions of auditory experience as evoked within the context of the soundscape of Johannesburg. Three variants of the soundscape of Johannesburg mediate the discussion: the city, the residential areas (leafy suburb and township) and the industrial zone. This is then followed by a series of case studies intended to suggest new ways of studying the soundscape of Johannesburg. In the final chapter, I provide an survey of sound art in Johannesburg and conclude by returning to the question of sound art and the experience of space and time itself.

**Keywords: Sound Art; Johannesburg; Soundscape; Audition; Acoustics; Perception; Music**

# INTRODUCTION

> …sound is not a medium that developed through a clean linear trajectory and ended as a real movement like Futurism or even Fluxus … it's a real messy history that includes a lot of wonderful things.
>
> (Rodin, quoted in Licht 2007: 9)

Sound art tends to assimilate and appropriate. Contemporary analyses reveal how sound art finds ways of making theories, histories and practices other than its own apply to itself. This paper will attempt to show the development of sound through history and make evident that sound art's history comprises a confluence of tributaries some of which stretch far back in human cultural history. One of the aims of this paper is to extend my master's dissertation entitled *Sound Art in Johannesburg: A Critical Review 2005-2009* (2010). What was clear from that work was the relative lack of critical discourse on sound art in Johannesburg. Although the discipline has gained momentum since, a complementary relationship between practice and theory, insofar as sound art in Johannesburg is concerned, is still in the early stages of development, and thus this paper hopes to add to the dialogue on sound art today. This research takes a circumspective approach by drawing together threads from archaeology, music, art, science and psychology as a means of informing a consideration of the importance of sound art in Johannesburg. It is based on the consideration that any serious interest in sound art should be informed by scientific knowledge of sound and hearing, the history of music, and cultural and technological developments that have eventually resulted in the emergence of sound art. Because many of the disciplines that contribute to a full understanding of sound art are beyond my area of expertise, much of my research depends on secondary sources.

Chapter 1, "The Origins of Hearing and Beginnings of Music", proposes that hearing originally evolved out of a need to provide early aquatic organisms with a means of communication that was more accurate than chemical communication, and also to provide them with an 'acoustic image' of their environment. The mechanisms for interpreting binaural cues and directional information as well as stream segregation were important developments in early aquatic animals. Evidence suggests that the ability to localise sounds was more likely useful for defence than for accurate communication. The adaptation of hearing during the transition from aquatic to terrestrial life posed a number of challenges that were solved over many millennia. During the course of this long evolutionary process, human speech evolved in parallel to hearing and, as a result, there are features of human hearing that are uniquely adapted to be receptive to speech. Some of these features relate to the biological mechanics of the ear itself and others to the way in which the specialisation of the auditory tools serve to receive speech sounds. Here, there is an overlapping of the emergence of language and the emergence of music.

To our early ancestors, hearing was directly related to survival and the physiological mechanisms of hearing have not changed much since. Archaeological evidence suggests that prehistoric communities were particularly sensitive to the sounds of their environment and it is also likely that these sounds were spiritually significant to them. The acoustics of Palaeolithic cave sites and open-air sites are compared in an attempt to discover whether the location of cave paintings was in any way related to the acoustics of space. Sites in which early rock gongs are located provide evidence of a link between the beginnings of music and its ritual and spiritual significance. The common ancestry of music and language suggests that music did not only develop as a means of reinforcing social bonds but was also a communicative medium. The progression from hearing as a means of providing us with detailed information about the environment to the apprehension of sound, in all its complexity, in order to communicate and reinforce social bonds, is nothing short of astonishing.

Chapter 2, "Sound and the History of Music", begins by extending the notion of the spiritual significance of sound in relation to early musical instruments. The numerological basis for early music theory, whether Sumerian, Egyptian, Chinese or Greek, provides an insight into the significance of cosmology to what would ultimately be translated into musical sound. Here, Pythagorean ideas of harmony would have lasting influence and are one of the most significant developments of the Ancient period. The emphasis in early medieval music was on song and an interest in the acoustics of churches, as mediators of divine words began to emerge. In this sense, the relationship of harmony with mathematical principles were seen as God-given, whether in the proportions inherent in musical scales or in the proportions of building. It was only towards the end of this period that note clusters and chords began being used for their perceived harmony. A more concerted focus on the human qualities of music characterises much of the music of the Renaissance. There were experiments in orchestration and writing music for a specific space and composition was beginning to emerge as an art form. The importance of orchestration and space as a composed element of music was further developed during the Baroque period. There was an interest in tuning and temperament for the emotions that sounds could potentially elicit, and purely instrumental music was also gaining prominence. The Classical period drew from the rise of instrumental music and took a more studious approach by listening to music for its purely sonorous qualities. Non-musical sounds, in the form of percussion instruments were also introduced. This study of sound in music also coincided with numerous discoveries in the science of sound. The Romantic period introduced the 'total work of art' but also saw the introduction of new instruments into the orchestra, which demanded more detailed theories of instrumentation and orchestration. The Modern period begins with the freeing of tonality and rhythm, a blurring of the distinction between musical and non-musical sound and the intentional use of noise. This coincided with the invention of sound recording and playback. An expanded vocabulary of sounds as well as new technologies of sound encouraged a climate of experimentation in the form of electronic music and *Musique Concrète*.

There are two key features in the development of music that enabled sound art to emerge in the first half of the twentieth century. The first is spatial. The art of orchestration developed an attentiveness to the spatial implications of musical sound and as such the performance space, too, came to be seen as a composed element of music. In some cases, it can even be said that space was an instrument as well. The second is sonic. Ideas of what constitutes musical sound had become gradually more complex and more accommodating. As equal temperament became the norm, there were moments where dissonance and non-musical sounds were introduced. As a result, the world of music became more permissive about what could be considered musical sound. That musical acoustics was embraced as a compositional element and that the pallet of musical sound became as unrestricted as it did, is also a consequence of the science of sound and developments in the technology of sound. In the former case, music became more secular and, in some instances, more concerned with form.

The development of music into a major form of cultural expression forms the background for the emergence of sound art in the latter half of the 20th century. Orchestration, the use of space as a composed element of music, the expansion of the domain of music, an increased interest in sound beyond music and the invention of recording and playback were influential, Chapter 3, "Sound Recording, Playback and Sound Art", begins by paying close attention to the technological narrative in relation to sound art. Sound recording went through three phases: analogue, electric and digital. Sound recording and playback technology allowed for new conceptions of space and time in relation to sound. As space and time became unfixed, new temporal sequences and spatial environments could be constructed. The manipulation of sound developed through a cross-pollination of techniques developed in the radio, film and music industries. Electrical amplification had a major influence on how recording happened in controlled environments and how more attention was paid to the acoustic treatment of spaces for listening. Recording studios were and sound equipment was, to a large degree, out of the reach of the general public, but with the birth of the digital era and the home computer as well as other media, working with sound became easier. Not only was there a technological basis for the emergence of sound art, but the rise of spatial practices and art forms that made use of sound became more pronounced in the second half of the 20th century. This, coupled with the democratisation of sound technology in the form of the home computer and related media, provided the ideal conditions for the emergence of sound art from the second quarter of the 20th century onwards. Whereas sound in art had generally been placed in the background and had functioned in support of the visual, during the period of the emergence of sound art the foregrounding of sound became frequent. The potential for the visual to support sound as well as the exclusive use of sound had set the scene for calling these works 'sound art'. What followed were numerous attempts to bring sound art under discursive control and in so doing many theorists focused their attention on defining sound art. In response to these definitions and as a means of setting precise limits for the understanding of sound art, Chapter 3 concludes with a working definition of sound art.

Having established the historical and theoretical framework for sound art, Chapter 4, "Sound in the Physical World", forms an important reference point for a fuller understanding of sound and hearing. This chapter begins by introducing the reader to the quantifiable variables in the physical properties of sound and the biological mechanisms of hearing. This is not to say that sounds are observer-independent but rather that the physical world and the physiological components of hearing form a background that affects our perceptual capacity. As a result, an understanding of what sound is and how it behaves as well as how human beings hear, has practical applications for sound art. To illustrate this, the way in which sound changes from one biome to the next is discussed, drawing from the scientific understanding of sound. This ultimately frames the understanding of the soundscape within the context of the diverse acoustic signatures of the environment and situates human hearing and soundmaking within the broad bioacoustic domain.

Whereas Chapter 4 discusses space and time as absolute, Chapter 5, "Sound in the Perceptual World", deals specifically with the experience of space, time and sound within the context of qualitative subjective states of awareness. Here, it is postulated that auditory experience requires an awareness of duration and that auditory perception of space is a function of time. This notion is reinforced by a detailed analysis of auditory spatial orientation, sound source localisation, the auditory perception of motion and the auditory perception of spaciousness. This now more lucid understanding of the perceptual mechanisms of audition is then extended into a discussion of the soundscape of Johannesburg.

Here there is a tension between the legacy of racial segregation manifested in spatial terms and the ability of sound and hearing to transcend these spatial demarcations. One of the primary purposes for which hearing evolved was the ability to hear beyond the immediate spatial environment, yet to a great extent, the soundscape of Johannesburg remains divided into particular zones of transmission. What this paper gestures towards is the potential for sound to be a unifying force within the context of post-apartheid Johannesburg. The question is: how can sound artists intervene in ways that demonstrate this potential? Thus, this chapter concludes with a number of studies that I believe approach the question of the soundscape in innovative ways. In order to initiate this discussion, Chapter 6, “Sound Art in Johannesburg”, begins by providing a brief critical survey of recent work. One of the aims of this survey is to outline several different approaches by sound artists to the sounds of their environment and to determine how, if at all, this speaks to the spatial questions inherent to the soundscape of Johannesburg. With the aim of encouraging further scholarship and artistic practice, the chapter concludes by providing several suggestions that pertain to soundscape studies as well as a brief overview of sound art in relation to the experience of space and time itself.

# CHAPTER 1: THE ORIGINS OF HEARING AND THE BEGINNINGS OF MUSIC

## The Evolution of Ears and Hearing in Brief

Since research in evolution falls outside of my area of expertise, this chapter necessarily relies very strongly on secondary sources. By drawing on these sources, my aim to provide an evolutionary overview of ears and hearing and of how spatial orientation and communication are central to understanding sound. Our human ancestors shared a fascination with sound for reasons that will become clear. One of the aims of this paper is to recall these fundamental features of hearing in order to inform new ways of engaging with the auditory environment.

During the Cambrian Period, approximately between 542 and 488 million years ago (Nelson 2006: 16), *agnathans* or jawless aquatic vertebrates developed what is thought to be the fundamental anatomical components that would allow them to hear. The vestibular labyrinth, which is basically a set of fluid-filled canals that make use of specialised hair cells, known as sensory epithelia, transmitted information about motion in a three-dimensional space. Although *agnathans* possessed no specialised organ for sound detection, their vestibular systems would have allowed for the detection of low frequency sounds. (Ladich & Popper 2004: 97)

Later, during the Silurian Period, approximately between 443 and 416 million years ago, the first aquatic jawed vertebrates, or *gnathostomes*, appeared. The gnathostomes had a highly diversified vestibular labyrinth and sensory epithelia, and Ladich and Popper suggest that *this* is the likely starting point for the evolution of vertebrate hearing. (Ladich & Popper 2004: 97)

The evolution of vertebrate hearing happened for two important reasons, firstly as a form of interspecies communication and, secondly, as a means of providing the fish with an acoustic image, or what Bregman calls the "auditory scene", of its environment. (Bregman 1990: 73) According to Popper and Schilt, lack of light, water turbidity and a limited line of sight make seeing under water fairly unreliable. Furthermore, chemical communication is generally only effective within a short range. (Popper & Schilt 2008: 19) Therefore, as a means of survival, hearing sensitivity in fish is an adaptation that allows them to perceive their environment to a far greater extent than is possible with any of their other senses.

The development of vertebrate hearing was dependent on three major abilities, namely: stream segregation, signal detection in the presence of interference and sound localisation. (Ladich & Popper 2004: 98-100) Evidence suggests that early vertebrate hearing had the ability to perform all three of the above-mentioned tasks. Stream segregation is the ability to discriminate between sounds that are not biologically relevant and those that are. Although biologists have not yet identified the mechanism for this ability in fish, studies have shown that they can differentiate between sound intensities, detect amplitude-modulated signals and detect specific sound signals in the presence of other sound. (Popper & Coombs 1979: 417)

In terrestrial animals, directional information is provided when peripheral differences are analysed at a central point through the stimulation of two different auditory receptors. Furthermore, the slight time delay of the auditory stimulus or 'binaural cues' gives the animal a sense of where a sound is coming from. Fish, on the other hand, receive directional information by direct stimulus from the particle displacement of a sound wave under water. This is most likely because the sensory epithelia of fish are not only grouped into like-orientated patterns (Popper & Schilt 2008: 23) but also because these patterns are arranged along different body planes. This makes the inner ear of a fish ideally suited to underwater hearing and sound localisation. (Popper & Coombs 1979: 418 – 421)

The transition from the Devonian to the Carboniferous Period, approximately between 416 and 299 million years ago, is the next pivotal point in relation to the evolution of hearing because this transition plays host to the evolution from aquatic to terrestrial audition. *Tetrapods* of the Devonian Period were the first vertebrates to have evolved four limbs as opposed to paired fins. (Stiassny 1996: 454) It is important to note that most of the early tetrapods were still essentially aquatic and most likely did not have an evolved tympanic ear. Therefore, the ear structure would still not have been adapted to terrestrial hearing and would probably only have been sensitive to low-frequency aerial sound, better suited to aquatic hearing. (Clack & Allin 2004: 133-135)

The challenge lies in being able to adapt to hearing in air as opposed to hearing under water. Sound travels faster in water than air because air is more elastic than water; I will discuss this in greater detail in Chapter 4. Terrestrial vertebrates had to adapt to this change by overcoming the difference in acoustic impedance between the low impedance of the tympanic membrane and the high impedance of the oval window. (Mather 2006: 92) There are three components that evolved during the transition from the Devonian to Carboniferous Period that are crucial and unique to aerial hearing.

The first is the formation of dedicated auditory end organs such as the basilar papilla and the cochlear nuclei. Already present in a primitive form in all tetrapods, the basilar papilla is a specialised auditory end organ consisting of a population of specialised hair cells, embedded in a gelatinous membrane structure and situated in the inner ear. (Coffin et al. 2004: 64) The basilar papilla of mammals is embedded along the inside of the cochlea, a coiled shell-like structure that is wide at its opening and has a tapering end. The basilar papilla and the coiled cochlea are responsible for making frequency and amplitude discriminations. (Wells 2007: 327)

The second is the periotic system, which developed differently in *amphibians* and *amniotes.* Situated in the inner ear, the periotic system consists of fluid-filled chambers and ducts that are surrounded by thin scale-like cellular walls or squamous epithelia. These walls, ducts and chambers are collectively known as the periotic labyrinth. The motion of the periotic fluid, induced by oscillating sound from the middle ear, stimulates the hair cells of the basilar papilla. (Hanken & Hall 1993: 262)

Lastly, a pressure transducing structure mediates acoustic signals from the low-density sound in air to the high density of the periotic fluid. There are two structures responsible for this, namely the middle ear and the tympanic membrane. The middle ear is an intermediary air space which funnels air-borne sound from the tympanic membrane to the inner ear by means of tiny bones called middle ear ossicles. The tympanum is a stretched, low mass membrane, also known as the ear drum, and receives environmental sound which it then transmits to the middle ear ossicles. (Fritzsch 1999: 21) The middle ear ossicles then transmit these vibrations to the oval or vestibular window, an opening that separates the middle and inner ear by means of a thin membrane. Pressure transducing systems are thought to have developed independently during the diversification of tetrapods. Those of *amphibians* are the oldest and those of *mammalians* the youngest (Hanken & Hall 1993: 263). I will focus only on the latter.

In the Permian period, between 299 and 251 million years ago, there was a large-scale diversification of *reptilian* orders, and one of the many lineages included *synapsids* or *premammalia*. The tympanic ear of the *premammalia* would have placed them at a competitive disadvantage in relation to their predators that already had ears that were better suited to terrestrial hearing. As a result, their numbers as well as their size decreased (Tumarkin 1968: 22-32):

> Ironically, this very miniaturisation in defeat gave them the air sensitivity that had eluded them in their prime, because of the concomitant area to mass ratio. The essence of an air conductor is a large collecting area and a light ossicle, and in shrinking from as much as 10 feet to as little as three inches they would increase that ratio by a factor of as much as forty.
>
> (Tumarkin 1968: 31)

This increased surface to mass ratio, as well as the transition to a triple ossicle mechanism from the inherited tympanic mechanism, define the early beginnings of the modern mammalian ear. This evolutionary process occurred from the earliest mammals of the Triassic period, about 200 million years ago, to the mass extinction at the end of the Cretaceous period, approximately 65 million years ago. An estimated 80-90 percent of all mammals did not survive the late Cretaceous extinction. However, the few that did proliferated into a vast diversification and radiation of species during the first third of the Cenozoic Era that followed. (Rose 2006: 2) Furthermore, continental drift and the gradual breaking apart of the major landmass, Pangaea, allowed for evolution and genetic diversification of one lineage in relative isolation from others. (Feldhamer et al. 2007: 58) One of these surviving mammalian species were *eutheria*, or placental mammals, the early ancestors of rodents, canines, carnivores, marsupials, whales and dolphins and many more including, most importantly, primates.

Dating back to the early Palaeocene period, primates are considered one of the oldest *eutherian* orders, but the first 'modern' primates are generally considered to be from the Eocene, approximately 55.8 million years ago. The specialised ears of Eocene primates developed in relation to environmental and behavioural conditions and have not changed dramatically since. (Campbell 2009: 246) Factors such as diet, geological conditions, climate change, nocturnal/diurnal preferences and communication efficiency are just some of the primary influences on the anatomy, physiology and, consequently, the variety of primate ears. (Delson 2000: xxi – xxiii)

Fundamentally, the primate ear has several shared anatomical characteristics. The ear consists of the outer, middle and inner ear. The outer ear consists of the pinna or auricle, two cartilaginous forms on the exterior of the cranium that direct auditory signals to the tympanic membrane via a tube. The pinna of nocturnal primates is much larger than that of diurnal primates, the former being far more dependent on hearing than sight. The pinna, for primates reliant on hearing in search of prey, sometimes have directional mobility. Furthermore, the pinna also functions as a thermoregulatory mechanism as the dilation of its blood vessels help to regulate body temperature. (Campbell 2009: 246)

The outer and middle ear are separated by a sheet of connective tissue called the tympanic membrane (also discussed earlier and in more detail in Chapter 4). The tympanic membrane changes environmental acoustic signals into mechanical signals and transmits these to the three middle ear ossicles: the malleus, incus and stapes. The stapes is the last bone in the triple ossicular chain and transmits the motion created by the tympanic membrane to the fluid-filled inner ear. The inner ear is sensitive to auditory stimulus as well as spatial orientation. The pressure sensitive snail-like structure or cochlea registers pressure fluctuations set in motion by the stapes and sends these signals to the brain. Spatial orientation and movement, as well as some low and high frequency sound reception, involve two maculae, the saccule and utricle, two sac-like areas that together form part of the vestibular apparatus. The other adjoining apparatus consist of three fluid-filled, semi-circular canals, namely the dorsal, posterior and lateral canals. (Fleagle 1999: 26-27) From this it is reasonable to conclude that the anatomy of primate ears is undeniably similar to humans. In humans, however, there are a number of improvements of this basic system that are seen in no other primates; I will discuss this in greater detail in Chapter 4; for our current purposes, a basic understanding will suffice.

Although this is highly contested terrain, the genus *homo* is generally considered to have diverged from an ancestor it shared with chimpanzees or *hominines*, approximately 5,7 million years ago. The several species that evolved from that node, such as *Homo erectus*, *homo neanderthalensis* and archaic *homo sapiens* have all become extinct. The 'Out-of-Africa' theory states that anatomically modern *Homo sapiens* evolved in Africa around 150,000 and 80,000 years ago, from whence it migrated to other parts of the world, replacing the preceding *Homo* species. (Stefoff 2010: 49)

Modern humans inherited their distinct ability to hear by a process of appropriation from other species. The co-opted reptilian jawbone forms the middle ear ossicles and the sensitivity to a broad frequency range is *mammalian*, while the capacity of the outer ear canal is common amongst primates. (Denny & McFadzean 2011: 199) Furthermore, the frequency range of modern human hearing begins with the enlarged earhole of *Australopithecus*, likely as a consequence of the change in habitat from forest to savannah that made it possible to hear frequencies above 2000 Hz. The head of *Homo,* too, became wider as the brain enlarged, making it possible to hear low frequency sounds. (Lieberman 2011: 399) Within this context, it is more likely that the derived features of modern human hearing evolved as a defence mechanism in order to localise sounds rather than for the purpose of communication. Despite this, hearing evolved in parallel to the ability to vocalise. It was prevalent amongst reptiles, mammals and primates, but became especially advanced in *Homo sapiens*.

As a consequence of the necessity to communicate, the vocal tracts of *Homo sapiens* are well adapted for speech. During hominid evolution, the larynx descended and the seal that assists in simultaneous breathing and eating disappeared, which allowed for a greater degree of articulatory control. (Hauser, 2000: 212) Furthermore, the lungs and associated muscles such as the diaphragm, control a proportionate airflow through the laryngeal cavity. The laryngeal cavity itself, consisting of muscles, vocal cords and cartilages, together with a highly manoeuvrable tongue and lips, allow for a wide and highly expressive range of vocal gestures. (Hauser 2000: 212)

The specialised adaptation of vocality in *Homo sapiens* also led to their ears having a number of design features modified for the purpose of aural communication. The pinna, for example, is fairly square and typical of ears adapted for a wide range of frequency reception including human speech, and the outer ear cavity further amplifies these particular frequencies. (Hauser 2000: 190) Naturally, the middle ear ossicles and cochlea are also adapted for the perception of this frequency range. This being said, sound localisation and aural communication are participatory adaptations in the truly remarkable *Homo sapiens* ability for auditory discrimination, tasked to the auditory cortex.

Situated on the supratemporal plane, the auditory cortex is connected to the cochlea by the ascending pathway. The ascending pathway itself consists of numerous interconnected processing centres and preliminary auditory stimuli can be analysed here. (Frackowiak 2004: 61) The auditory cortex itself is separated into the primary cortex, that is subdivided into different areas capable of processing auditory information in parallel, and non-primary areas that tend to overlap with other auditory, visual and somatic sensory areas that enable multisensory integration. (Gazzaniga 2004: 227) The evolution of the auditory cortex is the primary reason for the highly advanced discrimination and analysis of sounds and sound patterns concerned with human linguistic communication and as a consequence, the appreciation of music. (Campbell 2009: 247 – 248) Clearly the ability to hear is intimately connected to orientation in space and highly complex mechanisms of communication.

## The Prehistory of Sound

> The stone, the most enduring element of our planet, lives naturally with the primary elements; it lives with the fire, because many of the stones are born from volcanoes. The stone lives with the water, the first element for life on our planet, not only for man, naturally. It lives in the light, in the transparency where sun enters, where the wind enters, where the brightness makes us see the wonders of this

> world. The stone is the structure that carries our planet, the world's spine as the Incas said. Today's stones are the memory of the universe.
>
> (Sciola 2010: Beyond the Rock)

The development of bipedalism, the liberation of the forelimbs and the evolution of the human hand, was a case of temporally coinciding and anatomically harmonious adaptation. The gradual change from a forested habitat to grasslands is thought to have had a major effect on human evolution, encouraging bipedalism, as is already evident in early hominoids, of which the earliest known is *Ardipithecus* from the late Miocene period, approximately 5.6 million years ago. (White 2002: 410) As the grassland environment would not have provided sufficient plant protein, hunting and butchering meat made tool production necessary. (Haviland et al. 2008: 156)

Savage-Rumaugh and Fields propose a causal relationship between bipedalism and child rearing patterns, claiming that mother-to-child interaction, based on 'carrying the baby', was, and still is, the cornerstone of human language and subsequently the formation of the human self-concept. Human babies are heavy because of their large cranium and fat reserves and because their arms are too weak to cling to the mother, the mother is inclined to carry the baby in front of her or put it down. Because of these habits, the baby's sensory experience is distinctly different from its mother's. It has a sense of self as well as self-agency; linguistic dialogue is directed toward it such as when to be quiet, and it correspondingly communicates with its mother, suggesting that it is hungry. (Savage-Rumaugh & Fields 2011: 33-42)

The basic structure of the modern human hand with 35 muscles that manipulate 44 bones, as well as the neocortical system that direct the hand's sophisticated gestures, was already fully developed approximately 1.5 million years ago. (Hoffecker 2011: 48) Interestingly, there was a supposed tendency for early toolmakers to be right handed that accompanied an increased lateralisation of the brain, which is "linked both developmentally and evolutionarily with the appearance of language". (Haviland 2008: 189)

Given the phenotypic and genetic diversification and dispersal from Africa, Atkinson proposes an African origin for all languages, and it is generally accepted that human language is at least between 100,000 and 50,000 years old. (Atkinson 2011: 346-349) Atkinson's theory depends on the assumption that the essential physiological and socio-cultural properties required for human language and communication had reached full maturation by this time. I have already established the anatomical modernity of *Homo sapiens* during Atkinson's time period, such as the correlative evolution of the auditory and vocal anatomy. However, possessing the physical attributes for speech and hearing does not necessarily equate to the possession of language. Any discussion of language as a species-specific communicative trait must therefore also establish what the basic characteristics of human language are and how these served as a potential survival application.

In this respect, symbolic thought is commonly referred to as a distinguishing factor. Campbell explains that environmental reference to the presence of danger and food suggests that language had its origins in gesture. He proposes that adverbs and adjectives that consequently came into being to refer to distance (far or near), states of mind (happy or sad) and time (yesterday or tomorrow), would have communicated important survival information at a far more rapid rate than gestures could. The communication of symbolic thought, therefore, characterises human social activity. (Campbell 1995: 124-128) Thus language and intelligence evolved in a "positive feedback loop". (Campbell 1995: 128) Furthermore, bipedalism, the freeing of the forelimbs and the modern hand, as well as social and linguistic aptitude were the building blocks for humanity. This is perceptible in anatomical evidence and also in the documentation of our material culture. This early history is journaled in stone.

There are three major Lower Palaeolithic sites where the earliest stone tools were found. The oldest is from the Hadar in Ethiopia, dating back to between 2.5 and 2.6 million years ago, followed by the Tanzanian Odluvai Gorge and Kenyan Lake Turkana sites dating back to 2 million years ago. The tools were made using the 'percussive method,' striking two hard stones together to create stone flakes. As crude as they were, these tools enabled their users to cut meat, reeds and wood. (Haviland et al. 2008: 154 -155)

Stone tools reached a high degree of sophistication during the Middle Stone Age, or

Middle Palaeolithic, which started between 100,000 and 200,000 years ago and lasted until between 40,000 and 20,000 years ago. (Schick 1995: 59) Tools during this period became lighter and smaller. Hand axes, flakes, scrapers, borers, notched flakes for scraping wood and many types of points that were attached to wooden shafts are all indicative of tools specifically tailored to the task at hand. This tool-making tradition is known as the Mousterian tradition, named after the Neanderthal cave site in France, Le Moustier, and comparable tools of this type have been found across Europe, Western Asia, North Africa, China and Japan. The toolmakers also mastered the habitual, as opposed to opportunistic, use of fire during the early part of the middle Palaeolithic, produced by wood on wood friction and/or by the percussion/friction method, i.e. sparks resulting from flint tools made of stone. (Roebroeks & Villa 2012: 44) The middle Palaeolithic tool-makers had already developed a modern brain size between 400,000 and 200,000 years ago, had greater technological prowess, cultural maturity and are thought to be the progenitors of spoken language. (Haviland et al. 2008: 186)

Upper Palaeolithic tool-making was more efficient than in the preceding Middle Palaeolithic and between 50,000 and 10,000 years ago tools for hunting such as spear throwers, the bow and arrow and nets emerged. These stone tools were not only better suited to the task, with their makers being able to manufacture a highly specialised array of tools, but also regionally specific. Environmental and faunal factors delineated the kind of prey available and consequently the form of the tools used in the hunt. (Haviland et al. 2008: 205-207) Upper Palaeolithic humans lived in caves, rock shelters and built structures out in the open. They wore rudimentary clothing, made stone-lined pits for cooking and engaged in regular long-distance trade.

It is clear from the development of stone tools during and beyond the Stone Age that this readily available resource, opportunistically crafted, must have been highly valued. Given the evidence for stone and stone technologies being highly prized, I will henceforth investigate the potential of the symbolic pertinence of stone to lithic cultures by way of a discussion of three phenomena: 1. The acoustics of cave sites, 2. *In situ* stone assemblages maneuvered in accordance with acoustic factors and 3. Stone instruments such as lithophones or rock gongs and stone hand clappers.

Our Stone Age ancestors would have been far more acutely sensitive to their aural environment than we are today, not only because their environments were less cluttered by noise but also because sound was directly linked to their survival. It is possible that cave sites worldwide reinforce the presence of this sensitivity in that they show the recognition of the cave's acoustic properties in the form of resonance, reverberation and echo. Some archaeo-acousticians even believe that the presence of such properties might have been an important or even deciding factor in the selection of cave dwellings and sacred places. (Cox 2010: 2)

The earliest evidence of pigment use, more specifically hematite or red iron oxide, by hominids is from the Twin Rivers site in Zambia, dated to 300,000 years ago. (Barham 2004: 115). Modern human use of pigments dates back to the Middle Palaeolithic, as proven by examples from Blombos cave dating back to 140,000 years ago, where debris that not only indicates human activity but also includes 41 perforated beads indicating an awareness of social status, as well as a red ochre piece with an etched geometric design indicating the presence of abstract thought and symbolic language, were found. (Cremin 2007: 37) The majority of Southern African rock art authorship is attributed to the San (Lewis-Williams 1990: 4) that inhabited the area from 120,000 years ago. However, possibly as a consequence of climatic conditions and weathering, the earliest evidence of San symbolic culture, the Namibian Apollo 11 site, only dates back to 27,000 years ago. (Barham 2004: 115)

The Southern African San's physical-spiritual-emotional realm is one of sensorial coalescence and rock art sites are places of meditation, questioning and reinforcement of individual and social order, as well as transient places where the passing between the extra-ordinary spirit world, middle world and ordinary world is made possible through all the senses. (Ouzman 2001: 238) The world of ordinary human beings, potent animals, lesser and greater gods overlap at these sites. In much the same way that people commonly look to the skies, the San look and listen to the surface of the rock.

Studies related to the acoustic properties of cave painting sites are related to Upper

Palaeolithic Europe and North America and research of rock engraving sites or Southern African painted sites is sparse. Waller attempted to create a representational model for the relationship between cave art sites and their acoustics by conducting a series of recordings of open air, shallow and deep cave sites using a spring-loaded device that simulates the sound of human clapping. In doing so, he found that the open air, concave shape of the surrounding cliff face at Arbi du Roc-aux-Sorciers (The Sorcerer's Rock) in Vienne, France, creates a clear series of echoes that seem to emanate from the location of the stone reliefs, carved some 14,000 years ago. An increased clarity of echoes, specifically when stones are struck together, is heard as a result of leafless trees during winter at the rock art sites of Castel-Merle that are spread along the small creek joining the Vézère. Some of these sites, such as the engravings of Abri Castanet, have been dated to 37,000 years ago. The Cap Blanc, Commarque, Laussel, with engravings from the Magdelanian era approximately between 18,000 and 10,000 years ago, produces distinct echoic intonations. (Waller 1993: 3-4)

Open-air sites are set in the landscape and soundscape of outdoor environments. Consequently, textural flora, moulded terra firma and topographical features reflect and absorb, channel and orchestrate its sonorous substances. These sites are relatively uninsulated, and sounds emitted within this distinctive sonorous plateau are more likely to be inseparable from the audible environmental ambience, consisting of everything from the sound of water to the breeze, birds and other animals. Within this multiply stratified and sonically dynamic outdoor environment, that consists of a mixture of haphazard and coordinated sounds, Palaeolithic people not only exhibited an acute understanding of the pre-existing acoustics of the landscape but, in some cases, also arranged lithic and megalithic elements that seem to be acoustically significant.

The importance of landscape to open-air sites is as varied as their locations. Although archeologically tentative, the anthropomorphising and mythologizing of the landscape in a way that suggests the inseparability of nature and culture is a recurring theme. (Bender 1998: 40) In some cases, the symbolic connotations of rocky outcrops in their natural formation, protruding from the surface of the earth as well as offering a resource for toolmakers, represent the power of the ancestors who created the landscape, as is the case with the Arnhem Land in Australia. (Taçon 1991: 192-207) In other instances, these rocky protuberations were both the medium through which the spirits could be heard (Chippindale & Nash 2004 :305) and the portal to the spiritual realm (Lewis-Williams 1990: 5-16), as is the case with San rock art sites such as Klipbak I.

Situated in an elliptical basin on top of an isolated hill in the Korannaberg Mountains of the Northern Cape, Klipbak I contains 948 cultural markings comprised of 856 spherical ground hollows, 85 banded circular motifs, 32 abraded shallow elliptical hollows, 9 animal figures and 2 human figures. (Rifkin 2009: 586) Although no attempts have been made to date the site as yet, San engraved art traditions are dated variously from 8,400 years ago, 10,000 to 4,000 years ago and even 60,000 to 80,000 years ago. Rifkin comments on a series of echoes heard from various locations at the site and even a singular sound perceived as returning to the ear from numerous rock faces. He proposes that the rock faces from which the reflective sound emanated must have been perceived as having supernatural potency (Rifkin 2009: 597) and because of the site's water source, prevailing medicinal flora and the natural amphitheatre-like elliptical topography, Klipbak I could have been seen as a place where particular gods resided. The shaman, aided by ritualised song, dance and percussion, facilitated access to the gods' supreme guidance and healing. (Lewis-Williams 1990: 15)

Acoustics and settings within the landscape are two predominant ways in which cave sites differ from open-air sites. In the former case, hearing is a primary form of navigating through a cold, dark cave, albeit with the help of natural light entering the cave or flame torches, which would still have made vision fairly inadequate. They are relatively devoid of ambient, environmental sound and sonically isolated from the soundscape of the surrounds. The acoustic properties of caves are more suited to the production of reverberation and resonance than echo (Waller 1993: 4), resulting in an amplification of sounds that would ordinarily be discrete. As fissures within the topographical epidermis of the landscape, caves tended to be perceived as entrances into a world of transformation and regenerative power. (Hume 2007: 8)

As ruptures of the earth's membranous surface, caves are doorways into heightened sensation and the dwelling place of the gods. For the Southern African San, the actual surface of the cave walls acts as a curtain that partitions the real world from the spiritual world. In trance, the San shaman-artists became the mediators between these worlds, smearing the rock's surface to facilitate access, painting ethereal illuminations, "making non-ordinary reality a reality for ordinary people". (Lewis-Williams 1990: 15) Importantly, achieving this altered state is a communal accomplishment: the stomping of feet, clapping of hands, swishing of rattles and beating of resonating rocks guide the shaman's passage (Rifkin 2009: 597). The resonant acoustic properties of both open-air sites and deep caves are an integral part of this ritualised sonorous prologue.

Although no specific studies pertaining to the acoustics of any Southern African caves and their relationship to rock art could be found, Waller confirmed, through personal conversation with Ouzman in 2000, that the Rose Cottage cave, dated to the Middle Stone Age, was found to produce echoes and have "unusual acoustics". (Waller 2001: 7) Ouzman stressed that some painting sites do seem to have an acoustic element. However, Southern Africa tends to have decorated rock shelters or cliff overhangs rather than caves per se. He reconfirmed the unusual acoustics of the Rose Cottage cave and further mentioned Fulton's Rock, that has a stream underneath creating sound, as well as the existence of many engraved sites that are accompanied by ironstone rock gongs, of which I will speak later.

The deep cave rock art sites from Upper Palaeolithic Europe such as Les Combrelles in Les Eyzies de Tayac, Dordogne, France, has more than 600 engravings of animals and symbols dating back to 13,000 years ago. The sound quality at the entrance of the cave is generally poor and few engravings are present. However, the front, middle and inner galleries of the cave, where the reverberation is most intense, have the highest concentration of engravings. (Waller 1993: 5) The Cabiet des Bisons at Fon-de-Gaume, also located in the Dordogne Valley in France and dating back to 17,000 years ago, has uniform reverberation in the gallery where the images of ungulates are concentrated. Lastly, the cave at Cougnac from the Lot region, France, dated to two distinct phases, the first from 25,000 years ago and the second 14,000 years ago, has a clear sound-image relationship. The reflections at Cougnac increase the further one travels into the cave and the final chamber itself has unusually long reverberation times; there are hoofed animals painted on a facing concave wall from where the reverberation seems to emanate. (Waller 1993: 5)

The relationship between the choice of site and what is depicted in the painting of cave sites from Upper Palaeolithic Europe is debated. Waller's work seems to suggest that the location chosen for the painting had much to do with where the sound, especially echoes, emanated from during rituals. Because Upper Palaeolithic Cro-Magnon man became preoccupied with representing movement, the echo could have been of lesser importance than the attempt to represent the movement of galloping or stampeding hoofed animals. (Waller 1993: 7) On the other hand, Lewis-Williams argues that "hunter-gatherer communities throughout the world have religious practitioners who enter altered states of consciousness". (Lewis-Williams 1996: 324) and therefore shamanism was not only present at Upper Palaeolithic sites, such as those cited by Waller. The representation of movement could therefore have been expressions of ritual, not unlike in the case of the Southern African San mentioned earlier. (Lewis-Williams 1996: 326)

Ironstone rock gongs are another important element in Palaeolithic shamanistic ritual and occur commonly at engraved sites throughout Southern Africa. The percussive sound created by the clapping of hands and stomping of feet, accompanied by the metallic tones produced by striking the gong, is integral to San sound and dominated events such as the medicine or trance dance. (Ouzman 2001: 242-243) Although San engraving and the sound element of these sites are evidently an under-researched area, the sites exist throughout Southern Africa and the oldest can be tentatively dated to 14,000 years ago. (Ouzman 2001: 239) Klipbak I, mentioned earlier, has a rock gong and its surface bears numerous percussion marks. Although rock gongs generally have a limited tonal range, the rock gong at Klipbak I has a three-octave range. The natural resonance of the Klipbak I gong is further sonically exceptional given that it is located in a naturally echo-rich amphitheatre. (Rifkin 2009: 593-594)

In 1956, Bernard Fagg introduced rock gongs to the anthropological community when he discovered a number of rock gongs in Nigeria that were in close proximity to petroglyphs. Subsequently many examples from around the world were noted that varied in (1) size: from several tons to portable hand-held flint instruments, (2) date:

from Medieval to Megalithic to Palaeolithic and (3) use: for ritual purposes, communication over long distances and musical accompaniment. (Montagu 2007: 8) Following from (3), I have already discussed the ritual use of percussive sound and the acoustic characteristics of the landscape and how both were intertwined in the multisensory experience, using the San trance dance as an example. From these perspectives, sound as a communicative medium and the presumed development of music appear to be closely linked to our evolutionary narrative.

In summary, there is sufficient evidence that from our earliest beginnings, sound and music was of great importance. The ability to hear sound and the specialised hearing mechanisms that evolved during the transition from water to land, as well as the attunement of these mechanisms to habitat and behaviour, certainly aided our survival. Furthermore, music as a form of reinforcing social cohesion through ritual and the connectedness between the landscape and the ear, made evident through the acoustics of rock art sites, further confirms the particular sensitivity and significance of sound in prehistoric societies.

## Music and Language

Music and language are universal biological and mental expressions of human beings that make themselves manifest in a variety of culturally specific ways. (Hodges & Sebald 2011: 54) Biologically, "music appears likely to be rooted in neural circuitry and social processes that overlap, or share features with, those that constitute the matrix of language". (Cross 2010: 2) Therefore the neurological ability to process sonic aspects of music and language such as tone, timbre, rhythm and amplitude are uniform in all human beings, and not culturally specific; the tonal and rhythmic mechanisms that enable linguistic interaction are homologous with the musical mechanisms. (Cross 2010: 7) Cross proposes that the evolutionary bases for both music and language also have similarities which are primarily located in social interaction: reinforcement of group cohesion and consequently the reduction of group uncertainty. (Cross 2010: 7) Importantly, music and language are cultural artefacts with no fossil data to indicate their origins, yet Cross, and to a greater extent Molino, are hypothesising a common ancestry for music and language. Cross suggests that music and language evolved out of social necessity whereas Molino proposes that the rhythmic, melodic and affective semantic modules were the common point from which both music and language evolved in divergent ways. (Molino 2000: 165) Without over-reducing the variety of musical styles from around the world and noting that what is deemed music varies to a considerable extent, there are a number of universal cultural applications of music that are not without their similarities to language.

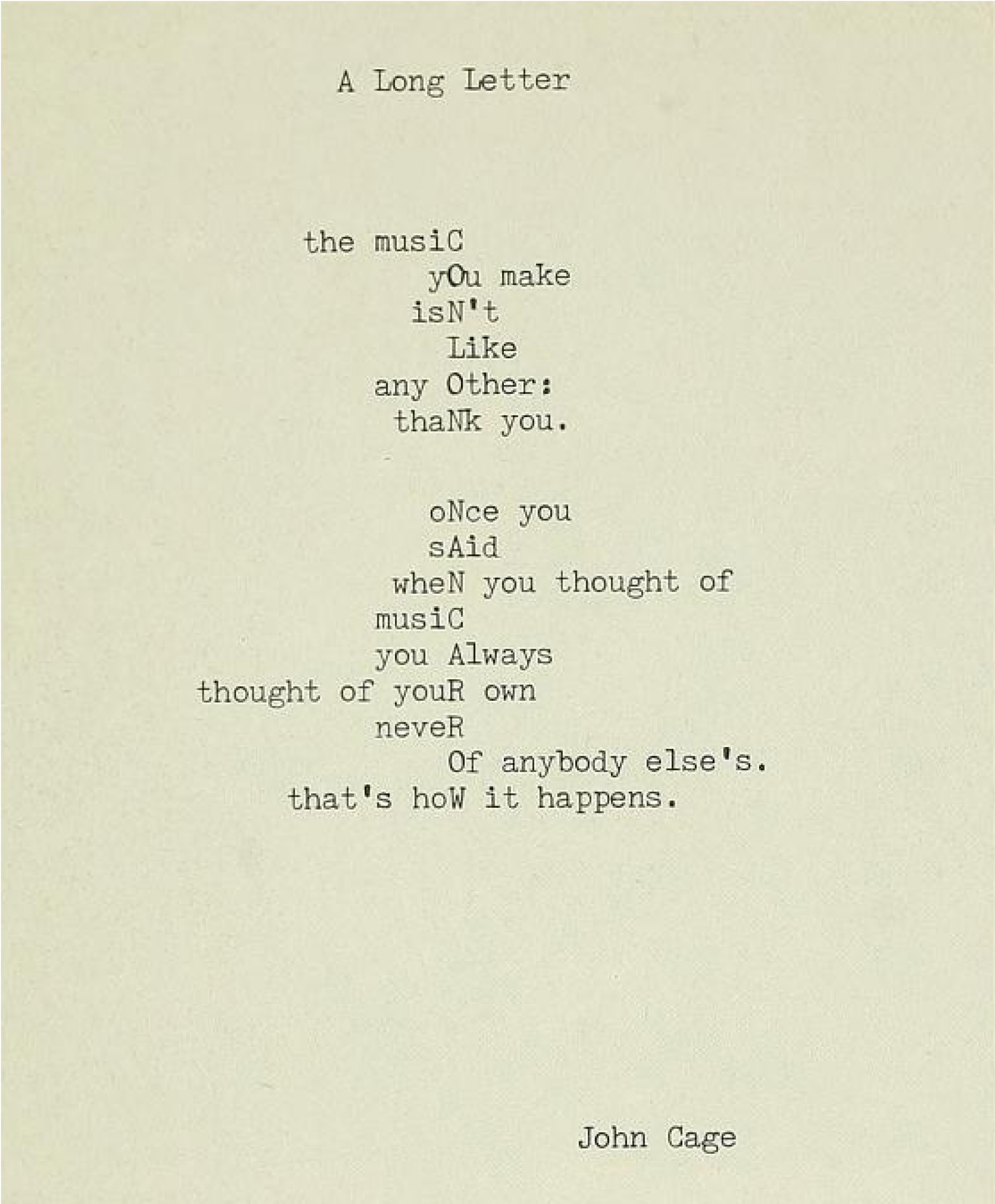
Linguistic communication is dependent on phonological, lexical and syntactical elements – lexicon referring to words, syntax to the combination of words into sentences and phonology to physical sounds – to create meaning and is a cross-cultural feature. Certain aspects of musical communication have both phonological and lexical dimensions, such as drum signals, where sequence, tone and amplitude are mutually understood between both sender and receiver. This, however, does not seem to be a generic cross-cultural feature of musical communication. (Hodges 2011: 61 & Cross 2010: 6) Of course, the ability to communicate does not presuppose music or language: there also is non-verbal gestural communication, but the degree of sophistication of human language and music is unparalleled. In language, syllable formation or more specifically morphemes are the material that, through the composition of speech rhythms, amount to phonetic articulation and ultimately sentence construction through varying combinations of lexical codes. (Molino 2000:173)

Similarly, music consists of timbres and tones, articulated through rhythm and strung together into a diverse repertoire of melody. However, although both language and music are forms of symbolic expression, language has the ability to be unambiguous whereas music displays “consistent ambiguity”. (Cross 2009: 13) This is where music and language diverge because the ascribed meaning of a word, both written and spoken, is predicated on the collective understanding of its assigned meaning, whereas music generally is comprised of unconsummated symbols and therefore has fleeting expressiveness and articulation. (Merriam & Merriam 1964: 234) Naturally, cross-overs exist. Language has tonal and rhythmic qualities and therefore does not strictly abide by its own rules; *how* things are said could therefore create ambiguity. Furthermore, in particular cases music could also have fairly fixed ascriptions of meaning, such as the assignment of sadness to minor tones in Western music. (Merriam & Merriam 1964: 237) These meanings are culturally specific and are reinforced over time.

Generally speaking, it can be concluded that the evolution of music and language must be primarily viewed as resulting from biological competences and secondarily as cultural. Numerous hypotheses exist in which an attempt is made to explain the reasons why music can be seen as a survival mechanism. Earlier I discussed Cross, who proposes that music developed as a communicative medium that reinforced social stability and cohesion. Other functional accounts range from music's role in parental care, sexual display, promoting the domestication of animals and promoting coordination, all of which have validity. (Wallin et al. 2000: 11) As a result, it can be surmised that there is no single reason why music evolved but rather that its origins are the result of the multitude of purposes it served.

The available evidence, in the form of early musical instruments and notation, should reinforce the hypothesis of the biological having primacy over the cultural. However, biological determinism that does not acknowledge historical contingencies "denies the importance of historical forces and cultural traditions". (Wallin et al 2000: 13) Granted, a universal factors such as the fact that most of the world's music consists of seven or less pitches per octave, that it is rhythmically devised into twos and threes and that emotional excitement is expressed by faster tempo and a louder amplitude all provide strong arguments for seeing music as universal; however, this could risk overlooking the richness of the cultural diversity evident in music. (Nettl 2000: 463)

Unlike linguistic universals, the trouble in postulating musical universals begins with the very definition of music, as stated earlier. Here, what is commonly referred to as music is often subsumed into a larger rubric of ritual practices, which makes it difficult to explain music in isolation. For example, the word *saapup* from the Blackfoot language group means singing, dancing and ceremony (Nettle 2000: 466), and the word *ngoma* from the Bantu language group is also a coagulation of drumming, singing, dancing and festivity; the Greek *mousiké*, too, refers to singing, dance and poetry over a pulse-based rhythm. (Merker 2000: 320) As important as it is to acknowledge the diversity of musical practices throughout the world, they often share the common goal of communication and reinforcing social bonds.



A Long Letter

the musiC
yOu make
isN't
Like
any Other:
thaNk you.

oNce you
sAid
wheN you thought of
musiC
you Always
thought of youR own
neveR
Of anybody else's.
that's hoW it happens.

John Cage

**FIGURE 1: Cage, J. *Long Letter* (no date)**

# CHAPTER 2: SOUND AND THE HISTORY OF MUSIC

In the previous section I looked briefly at the parallels and differences between music and language, both of which evolved out of a need for social cohesion as a function of communication. I made a brief comparison between universal grammar and universals in music and acknowledged the risk that claims about musical universals potentially undermine the richness and diversity of music across cultures. Sound art is mainly a Western phenomenon rooted in European music and art. In this section I provide a brief historical overview of Western music in order to point out some of the key developments that are important to the emergence of sound art. This begins with early musical instruments and how their tuning eventually came to be a numerological representation of cosmological order. What will become evident is that Pythagorean tuning would endure for many centuries. As music became more complex and diverse it also became more secular. This was often accompanied by a deeper understanding of the nature of sound.

In this section it will become clear how developments throughout the history of music contribute to a fuller understanding of sound. It is important to acknowledge that I am neither a musician nor a music historian and therefore this section relies strongly on secondary sources insofar as they provide insight into sound art.

The primary aim of the discussion that follows is to suggest that there are three key aspects of music that stimulated the emergence of sound art. The first is that the development of musical sound eventually resulted in a more inclusive approach that, at times, embraced dissonance and even the inclusion of non-musical sound. Secondly, the art of orchestration developed to include space as a composed element of music. Finally, there was the invention of recording and playback as well as other sound related technologies.

## Early Instruments

It is difficult to make concrete determinations about prehistoric instruments, how they were tuned and what, if any, symbolic significance the sounds they produced had. Modern knowledge of prehistoric instruments is based on three sources of evidence, according to Blades summarised below:

> 1. Archaeological evidence (excavations, ice, sand and peat bog deposits etc.)
> 2. Pictorial representations
> 3. Literary references, including studies of the numerous types of instruments among primitive peoples.
>
> (Blades 1992: 34)

It is safe to assume that prehistoric instruments, particularly those from Africa, were predominantly percussive and resulted in a diversity of idiophones. Idiophones are instruments that, when struck, the entire instrument produces sound. There are, however, exceptions to the purely idiophonic nature of African instruments. The *kalengo* or talking drum is a two-headed hourglass shaped drum held under the arm; when the strings of the drum are squeezed the drum produces different tones. (Blades 1992: 55) The xylophone, in all of its various forms, is perhaps one of the best examples of the genesis of a musical scale and has been found in use throughout Africa and Indo-China. (Blades 1992: 71) Lastly, the bow harp, made by early hunter-gather societies, is played by striking or plucking the string of the bow with the one end of the bow being placed in the mouth, which acts as a resonator. Because the tension of the string can be manipulated by bending the bow, the bow harp demonstrates tuning and temperament but in a spontaneous way.

In 2009, Nicholas J. Conrad found what is believed to be the earliest surviving evidence of a musical instrument in the Hohle Fels caves in Germany. With five finger holes carved out of a hollow griffin vulture bone, the flute-like objects are thought to date back to between 30,000 and 35,000 years ago. It is likely, given the degree of sophistication of the flutes, that they were not the first flutes, that the technology was brought to the area by the first migrating humans and that earlier flutes were made from ephemeral materials such as wood or reeds and have not survived. (Montagu 2007: 245) More importantly, the notion that these early instruments were designed with a particular scale system in mind has been the subject of debate. (Barbour 2004: 28) Recently, Wulf Hein reconstructed one of the ancient flutes out of the bone of an Andean condor, and what he discovered was that the flute was tuned to play the pentatonic scale. What Hein's work suggests is that early Upper Palaeolithic humans might have had a preference for particular musical intervals. (Mannes 2011: 167-168) It is unlikely that the complete story behind the Hohle Fels flutes, how they were played or what thought informed the tones they produced will ever be completely understood.

The extent to which the qualities of these sounds were informed by spiritual practice, or how ritual and ceremonial practice was facilitated by these sounds, is fertile ground for further discussion. For our immediate purpose it is sufficient to state that it is unlikely that the manner in which prehistoric musical instruments were crafted to produce particular sounds was incidental.

## Music in Antiquity

The Sumerian cuneiform writing tradition dates back to approximately 3,500 years ago. (Wallin et al. 2000: 10) Sumerian music accompanied sacrifices, ritual purification ceremonies and festive occasions. The cuneiform texts describe large ensembles of singers and musicians that typically played arched harps and large lyres (Randel 2003: 506) as well as drums and tambourines that accompanied singing. (Kramer 1971: 100) The texts also dictate specifications for the tuning of instruments and, in some cases, include the classification of the musical piece as a hymn. The Sumerians may also have ascribed sacred and mythological metaphors to their musical scale; for example, in the Sumerian Pantheon, gods were ascribed numbers that relate to the Sumerian musical scale. According to Kappraff, Sumerian mathematics, on which their harmonic law was based, was the first known use of mathematically modulated tonal ratios organised into a cyclic pattern. (Kappraff 2002: 56-57) The politically ascendant Babylonians (2100 BCE) inherited Sumerian cosmology, sexagesimal mathematics and, concurrently, their musical measurement. (Kappraff 2002: 77)

In sharp contrast to Kappraff's assertion, in China the practice of tuning court instruments was already well established 2,300 years ago and the Chronicles of the House of Lü (239 BCE) make reference to the reign of emperor Huang-ti, his musical minister Ling-lun and twelve pitch pipes constructed into a cycle of fifths and "tuned to the love song of a pair of phoenixes". (Han & Mark 1983:11) Furthermore, the Rites of the Chou Dynasty, written approximately 2,400 years ago, lists five scale tones, namely: *kung, shang, chiao, chi* and *yü*, with the addition of *pien kung* and *pien chih* towards the latter part of the Chou Dynasty. The Chinese scale was predominantly used for fixed tuning of court instruments used in ceremony, such as panpipes, stone chimes and bronze bells. (Han & Mark 1983:11) These were still early attempts to codify the twelve tones into an octave and it was only in 1584 that Chu Tsai-yü resolved the formula for equal temperament in his book *A New Account of the Science of the Pitch Pipe*. Chu himself traced the source of his formula to the Han dynasty and the Taoist king Liu An in 122 BCE. (Isacoff 2001: 233-234)

The climatic conditions of Egypt are ideal for the preservation of archaeological evidence. This and pictorial representations provide us with a very detailed account of how music featured in Egyptian antiquity. The earliest evidence of a predynastic writing system is from the fourth millennium BC from tomb U-j, the tomb of the King Scorpion, and comprises a combination of pictorial signs and abstract forms that represent numbers. (Imhausen 2016: 16) Evidence suggests that during this period, rattles and clappers were employed in musical practice for spiritual purposes. (Apel 1974: 282) Thereafter, during the Old Kingdom (2778-2160 BCE), harps, flutes and double clarinets appeared and during the middle period (2160-1580 BCE) drums from sub-Saharan Africa and lyres from Asia appeared. Studies of flutes from the Middle Kingdom suggest that music moved in large intervals, and that during the New Kingdom (1580-1085 BCE) there was a widening in the diversity of musical instruments and a deepening of its complexity. As a consequence, musical intervals also became shorter. (Apel 1974: 282)

The mathematical proficiency of the ancient Egyptians and how it featured in art and architecture is well documented elsewhere. (Imhausen: 2016: 170-176) Pictorial representations suggest that the mathematically harmonious relationships evident in Egyptian architecture were also applied to the manner in which instruments were made and tuned. (Sachs 2006: 94-95) Even though there was a wide variety of musical instruments based on a long enduring mathematical canon (Gadalla 2004: 6), "the discovery that tones can be measured in space" (Rossi 2003: 2) and that the consonances between tones depend on the ratios of simple whole numbers, is attributed to Pythagoras. (Hunt 1978: 10)

The essence of ancient Greek music was given birth through numbers and the father of the mathematical relationships inherent to musical consonance was Pythagoras (570-480), who learnt his geometry in Egypt and whose interest in arithmetical proportions was rooted in Babylonian science. (Mathiesen 2011: 258) Musical consonance was seen as a metaphor for the numerical relationships that, to the Greeks, were inherent in all things, nature and the heavens: "harmony…was perceived not only as a musical phenomenon but also as the dominant metaphysical principle of the universe". (Fletcher 2001: 125) Harmony, *armonia* (or *harmonia*) in the pre-polyphonic era of the Greeks, had a meaning that was unrelated to music and meant the perfect "fitting together" of objects. This eventually translated itself into the music theory of the time; however, it was used to describe pitch intervals in melody and not the combinations of tones. The concordance of sounds was called *symphonia* and the discordant relationships were called *diaphonos.* (Tenny 1988: 9-11)

Music was a combination of the artistic inspiration of the muses with the moral purpose of *ethos* and was a fundamental part of daily life, particularly as a means of celebration or as part of rites of passage, but it was also played competitively. (Randal 2003: 357) The use of the lyre was widespread and considered amateurish whereas the box lyre or *kithara* and paired *aulos* were the reserve of accomplished musicians. Although there were solo forms of music, choral performances were often accompanied by instruments. Music was primarily vocal, and the meter of choral pieces was closely related to that of Greek poetry. The nature of music was strongly influenced by the Greek language, that had both long and short vowels and pitch accents. (Randel 2003: 357)

Although Pythagoras believed that the secrets of the universe were to be found in the mathematical model of music and Plato (427-347 BCE) believed that music proposes the forces of good and therefore has the ability to shape personality, it was Aristoxenus (330 BCE) who wrote the first comprehensive theory for Greek music in *Elements of Harmonics* and *Elements of Rhythm*. (Sacks et al. 2009: 214) Evidence suggests that early Greek notation is derived from fifty short fragments, which have established the thought that musical notation existed as early as 400 B.C. (Fletcher 2001: 124)

The mathematical consonance of Pythagoras was influential for two important reasons. Firstly, the relation between numbers and astronomical concepts meant that any deviation from the numerical standard of tuning would imply a questioning of the mechanics of the universe and that any kind of reconfiguration in understanding the celestial sphere would consequently call into question the sonorous harmony as expressed by musical tuning. Secondly, the emphasis placed on numbers also meant neglecting the senses. The irony is that there was a fatal flaw in Pythagorean tuning. Octaves are based on multiples of 2 and fifths are based on multiples of 3. Both are prime numbers and multiples of different prime numbers can never be equal. This means that when one string is tuned to an octave and another string to fifths, the progression through the tones will become incrementally different and eventually out of tune. (Isacoff 2001: 65-66) Even though Pythagoras was aware of this, pure proportionality was the prevailing sonic language for many centuries to follow. However, a new conception of the universe and a demand for a more complex sensory experience would eventually call it into question.

Greek culture had widespread influence and the West, North Africa and parts of West Asia became increasingly Hellenised, to the extent that Greek became the official language in parts of Asia and North Africa. (Fletcher 2001: 129) As a result of a series of political events and war, and finally the Roman conquest of Macedonia in 167 BCE, Greek culture declined. Many Greek artists entered Rome and although there was much respect for Greek music, the Romans placed more entertainment value on gladiators than on musicians. This era saw the popularisation of pantomime, native in origin and dating back to 400 BCE. However, it was developed further by the immigrant Greeks. (Fletcher 2001: 131) The extent to which Greek music influenced Western music is unknown although the Neoplatonic, Neopythagorean and Aristoxenus' music theories were later translated into Latin by Boethius in *De Musica* (500). (Randel 2003: 358)

Notably, it is at this time, during the mid-20's BCE, that Marcus Vitruvius Pallio wrote the only surviving architectural work from the Roman empire, the *Ten Books of Architecture*, presented to the new ruler of the Roman world, Augustus Caesar. Focused predominantly on town planning, civic engineering and the design of public and private accommodation, the work places particular focus on the acoustics of public places and amphitheatre design in relation to voice projection. More specifically, Pallio cites Aristoxenus' observation that speech comprises, firstly, continuous progression without audible boundaries and, secondly, movements in a "stepwise-progression". His priority is audibility and how architecture can aid a speaker to be heard by him- or herself as reassurance and also by his or her audience, as well as designing private spaces that are acoustically insulated. (Maconie 377: 2010) When writing about amphitheatres, Vitruvius pays particular attention to musical modes and thereby establishes a theoretical system of building proportions based on the mathematical relationships between musical tones. Although this measurement system was not strictly adopted and it was more likely that the vocalist or instrument players had to adapt to the acoustics of amphitheatres, it is no less significant for its treatment of and sensitivity to sound in space.

## The Medieval Period

Although the precise dates and contributing events are debated, the transition between antiquity and the modern world is commonly marked by a thousand years, between 550-1450 and known as the Medieval period or Middle Ages. The Italian Roman Empire fell under the control of the Goths, Germanic tribes such as the Franks, Anglo-Saxons and Visigoths had growing empires that rivalled that of the Romans, and the majority of Europe was characterised by feudalism. The establishment of Islam in 600 CE initiated the Muslim expansion which encroached on Europe and ultimately led to the crusades; it also united the Far East and North Africa through trade. (Johnston, 2011: vii-ix)

The establishment of Christianity with its musical culture, most likely appropriated from the Jewish church (Tapper & Goetschius 2001: 33), was to have a far-reaching influence on Western music to come. The division of the Roman and Byzantine empires by the emperor Diocletian in 248 gave birth to two distinctly different musical styles. When Constantine moved his court from Rome to Byzantium, 'converted' to Christianity and established himself as *dominus* (lord), worship became public and liturgical chants such as communion, introit and offertory were developed. (Fletcher 2001: 132) By 400 there was a variety of Christian sects that practiced their own liturgical music, but they all foregrounded the primacy of the word over music.

(Fletcher 2001: 132) The music consisted of responsorial or antiphonal choral pieces that included both male and female singers; however, many instruments were prohibited. (Tapper & Goetschius 2001: 33) St Ambrose (333-397) is said to have been the forerunner in attempting to create a musical system for the Catholic Church, a system which was characteristically prosodic and became the fundamental form for his epoch. (Tapper & Goetschius 2001: 33) Meter was related to the rhythm inherent to speech and as there was no musical notation as such: tones were indicated by alphabetical letters similar to that of the Greeks. (Tapper & Goetschius 2001: 35) A more refined system was established later by Gregory (540-604), which depended less on the rhythm designated by words and was defined by spondee meter (long syllables). Above all, Gregory established the fixed chant or *cantus firmus* that was to become the standard of the Catholic Church for time to come and is known as the Gregorian chant, so named by the Franks. (Crocker 1986: 2) The Gregorian repertoire is occasion-specific, or rather designated to accompany specific liturgical procedures in which the word takes precedence over the music. At the centre of all liturgical actions was the mass, which has a relatively and perhaps intentionally simplified range of tonal variation. (Crocker 1986: 3) The development of chant occurred over time, with the respective Roman and Frankish contributions being at the forefront, but it generally remained a "monotonous mode of unison singing". (Tapper & Goetschius 2001: 43) This was music of obedience and restraint and the enjoyment of singing for its sonorous qualities was frowned upon. (Isacoff 2001: 74)

Significantly, it was the Eastern Roman Empire that facilitated the building of St. Sophia or Hagia Sophia (532-537), which is still one of the world's largest religious structures, the most pronounced element being its large dome. The building, and all early basilican churches, had rich reverberating characteristics and, acknowledging that little is known about how the early plain chant sounded, it is assumed that the singers would have adapted their technique and projection in order for words to still be discernible. (Long 2006: 10)

The next notable development in Western music was the association or combination of tones sung simultaneously. This is generally attributed to Hucbald or Ubaldus (840-930), a Benedictine monk who was an avid student of Greek musical theory. Initially the organum consisted of the simultaneous and parallel harmonisation of higher and lower tonal registers. Thereafter, diaphony was introduced, which consisted of changing melodic impulses and more euphonious melodies, finally culminating in polyphony. That this development arose within the church was a fortunate occurrence as it would otherwise have been viewed as a threat to the purity of the music. (Tapper & Goetschius 2001: 44) Later, the consolidation of various phenomena including polyphony came from the Benedictine monk Guido of Arezzo (995-1050), who also rejected the Greek tetrachord, replacing it with a six-tone scale that soon gained consensus. (Tapper & Goetschius 2001: 48) Interestingly, Guido also introduced sight singing and the association of scale patterns to memorised syllables known as *solfège*. (Apostolaki 2016: 223)

It is also within this context that the seeds of space as a composed element of music were planted in the form of antiphonal singing, the responsorial and the polychoral. Whereas the antiphon consisted of two halves of the same choir alternating between each other, the responsorial consisted of a singer or a small ensemble separate from the main choir (Apel 1974: 727), while the polychoral divided the choir into several ensembles that sang either in unison or separately. Of these three, the polychoral style became widely used. As a result, different melodic lines could travel in a variety of directions, deviating from and interweaving with each other.

The development of the pipe organ was also a Benedictine innovation, even though it was known to the Greeks and Romans before. The organ at Winchester cathedral (990) is notable in the history of the development of organs as well as for the magnitude of its acoustic presence. Organs at the time were placed at the door of the cathedral and the sound was manually produced by the breath of 70 men. Two organists were needed to play the two keyboards simultaneously to produce sound from four hundred pipes, which had a tonal range of 40 notes. The mere amplitude of the Winchester organ is said to have enveloped the entire town and in as much as it was used in celebration, it was also a call to service, similar to church bells today. (Fletcher & Rossing 1998: 552 & Baker 2003: 25-26)

The relationship between the musical traditions of the church and that of the secular world at this stage of Western musical development was one of reciprocity. Through the work of Guido's successors, the fundamentals of staff notation were already being used in a rudimentary form. Absent from this notation was an indication of timing, that seemed to have developed from secular music and was formalised by Franco of Cologne, who established the writing of time-values for notes in the mid-thirteenth century. A more detailed form of notation also led composers such as Pérotin to introduce note clusters, and hence the chord. In addition, the idea of consonance and dissonance also underwent a change during the 13th century. Even though musical theory was still strictly Pythagorean, theorists such as John of Garland, Franco of Cologne and Jacobus of Liége began to experiment with consonance and dissonance, which was based more on the degree to which two notes are perceived as harmonious, as opposed to their harmony being based on mathematical relatedness. (Tenney 1988: 96)

It was roughly at this period that troubadours and minstrels, mostly from Arabic Spain, became widespread throughout Europe. Self-trained and highly skilled, these musicians were more likely to indulge in subject matter that had little to do with the church and played and sang pastoral love songs. (Tapper & Goetschius 2001: 62) The most significant contribution of the folk music idiom was the introduction of rhythm and poetic meter into sacred music. The level of popularity of everyday music ultimately led to the adoption of folk song or attributes of folk music by the church (Tapper & Goetschius 2001: 79), as a result secular melodies that were more elaborate and more textured infiltrated the church despite numerous attempts to combat this. (Isacoff 2001: 79-80) The most significant contribution of the adoption of the folk idiom in sacred music was the introduction of rhythm and poetic meter.

## The Renaissance Period

The steady decline of the restrictive Christian convention can be illustrated by Giotto's frescoes. Rather than painting the modest faces and postures that were the norm, Giotto sought to imbue his subjects with the raw emotion of contemporary society and placed them in familiar landscapes. Instead of placing his subjects in a position where the viewer would have to look upward, Giotto placed his figure in the lower portion of his frame, at eye level, drawing the viewer into the scene. By using these methods, Giotto focused on the human qualities of his subjects. Petrarch described Giotto's frescoes as "images bursting from their frames, and all lineaments of breathing faces so that you expect shortly to hear the sound of their voices". (Pertrarch, quoted in Isacoff 2001: 82-83) It can be argued that the impact of the Protestant Reformation and the desire for people to hear music in their own language signalled a similar focus on the human qualities in music. This is apparent in the music of Jacques Arcadelt with its expression of human pleasure and, later, John Dowland's interest in people and their emotions.

In the same period that Giotto was painting his frescoes, there was also a renewed interest in the explorative and reciprocal relationship between music and mathematics that could possibly have been a result of the introduction of Arabic numerals, the sign for zero and the mechanical clock. As a result, the music of the time became more textured and greater skill was required on the part of the musician. Although the organ, based on the Pythagorean canon of octaves, fourths and fifths, was widespread in terms of keyboard music, the Renaissance saw a proliferation in the variety of keyboard instruments that resulted from the need for a broadening of the pallet of harmony. The most prolific of these keyboard instruments was the clavicembalum or harpsichord that also set in motion a musical tuning based on thirds. The compositions that resulted were richer in emotion, more dramatic, the musical equivalent of Giotto's frescoes. (Isacoff 2001: 85-88)

Earlier, I spoke of the way in which choral music brought auditory space to life by splitting the choir into different parts, where the song unfolds through a dialogue between these parts as the sound of the voice alternates between different spatial locations of the cathedral. This technique continued to be used and became a defining feature of the Venetian school during the Renaissance in the form of the *coro spezzato* or broken choir. Giovanni Gabrielli was renowned for his use of polychoral techniques, echo and instruments, and later became known as the "father of orchestration". (Apel 1974: 896) There were also instances of the polychoral technique being used in St Mark's cathedral, where two organs placed in separate apses of the cathedral played alternating melodies, with the choir divided into different parts and placed throughout the space. Gabrielli's treatment of space is an early example in the development of the orchestration of space to create an immersive sonic experience. During the Baroque period, the polychoral techniques initiated by the Venetian school would develop further in the vocal music of Florence and instrumental music of Venice.

Even though there was a trend away from the Pythagorean musical canon, it still persisted, and its influence was perhaps accelerated by the translation of ancient manuscripts. However, it was situated within the context of a vastly expanded musical vocabulary. Of particular importance here is the composer Guillaume Dufay and his composition for the dedication of the Florence cathedral, the Santa Maria del Fiore. Although much of Dufay's work combined influences from England and Northern Europe and made use of thirds in the spirit of the new musical order, the composition for the Florence cathedral returned to the Pythagorean ratio – but for reasons that differed from his predecessors. In brief, the construction of the dome of the cathedral posed problems because of the wide span across which the vault needed to be placed. Eventually Filippo Brunelleschi solved the problem by drawing inspiration from the Greek Pantheon (125) and ancient architectural proportion. This set of proportions was the starting point for Dufay's composition entitled *Nuper Rosarum Flores* (The Rose Blossoms Recently). It seems clear that the work was tuned to the space and the space was a composed element of the music. Dufay and Brunelleschi's work not only recalled a long tradition of how numerology influenced the design of holy spaces but also demonstrated a shift away from art based strictly on doctrine towards art based on experience. (Isacoff 2001: 114) In the years that followed, Brunelleschi would further his exploration and his painting is significant in this respect. In the spirit of Giotto before, Brunelleschi placed the viewer within the scene by using realism and one-point perspective that foregrounded human experience. However, music that could match the sophistication of Brunelleschi's perspective was still in its infancy.

During the early Renaissance, the medieval Scholastics who studied antiquity for the benefit of Christianity were gradually being replaced by the humanists, particularly through the work of Francis Petrarch and his interest in Cicero. The humanists foregrounded individuality and this break from the church, together with the declining importance of the ruling classes, had distinct consequences, initially for art and literature and later also for music. (Caferro 2010: 100) One important manifestation of this was evident in the field of education. The *studia humanitatis* was based on a pedagogical structuring of the *trivium,* consisting of grammar, logic and rhetoric, taught in preparation for the *quadrivium,* which included arithmetic, geometry, astronomy and music. Furthermore, in 1543, Copernicus published *Concerning the Revolutions of the Celestial Bodies*, which offered a heliocentric view of the universe, placing the sun at the centre of the universe, as opposed to the dominant geocentric view that placed earth at the centre. (Greer & Lewis 2004: 419) Galileo and his contemporary Kepler sought to prove that the earth revolved around the sun and they did so by means of a characteristically scientific method, proclaiming that the language of the universe is mathematical and that its forces can be observed. (Greer & Lewis 2004: 419 – 422)

The perspective painting to which artists like Brunelleschi and Massachio brought clarity with mathematical rigour now became, for men like Leonardo, a means by which to understand reality. The ancient debate between perception and reality is central to this shift towards observation by the senses. Whereas Anaxagoras claimed that "through the weakness of sense perception, we cannot judge truth" (Anaxagoras, quoted in Hunt 1973: 11), Protagoras said that perception is truth. (Isacoff 2001: 121) Whereas Greek numerology attributed mystical or religious significance to numbers, during the Renaissance, man became the measure of all things. This turn away from the spiritual to the secular that became visibly evident in the way that painters used perspective was also reflected in music, as Isacoff explains:

> So, like the painters, musicians searched for an accommodation between the ideal and the practical, for a way to reformulate the proportions between musical tones so they would produce desirable effects as they coalesced on the canvas of time. They wanted a new harmony of parts. They needed a recipe for musical perspective. The answer was temperament.
>
> (Isacoff 2001: 134)

The first two notable attempts at musical temperament took place towards the end of the 15th century by Bartolomeo Ramos de Pajera and Franchinus Gaffurius. Essentially the existing tuning method was based on old practices, but their idea was to adjust the tones in small increments in order to reconcile fifths and thirds. This is called mean tone temperament. Importantly, mean tone temperament was based on a perceptual premise: that the small variations in tone would not be noticed by the majority of listeners. This idea would later be extended upon and a composition that exemplifies it is Adrian Willaert's *Quid non ebrietas* (What cannot be achieved through inebriation?) (1519), in which he abandoned convention and simply divided the octave into twelve equal parts. This form of temperament was called equal temperament; it was a pivotal moment and the beginning of a fundamental debate in terms of the history of music. Advocates of consonance as defined by proportion, such as music theorist Gioseffo Zarlino, were confronted by a more primary question in the form of Vincenzo Galilei's musical relativism. The mathematics of music was in opposition to the auditory experience. Galilei noted that musicians improvised, and instruments gradually become detuned, and that most listeners did not notice this because music had less to do with mathematics and more to do with the experience of listening. (Isacoff 2001: 199)

The appearance of a prosperous middle class and the emergence of scientific method, along with the eventual development of commercial printing, that was only possible because Muslim trade brought the knowledge of paper-making to Europe, allowed for musical education outside of the church to occur to a larger extent than during the Medieval period. However, there was still a bridging of influences between sacred and secular music, as stated earlier. There was a greater diversification of musical instruments, as well as a wider and more specialised tonal and harmonic pallet that included consonances and dissonances. The musical prodigy and technique embellishment were also widely admired and along with the admiration of individuality, there was a real sense that through one's efforts alone great fame could be achieved, as was the case with Josquin and the quintessential high Renaissance composer, Palestrina. It is through the famed composers of this period that the combination of quadrivial science and rhetorical values of voice, that characterises Renaissance music, arose. (Haar 2006: 35)

In conclusion, the two most important contributions that the Renaissance made to sound art both developed out of the new emphasis placed on observation, as opposed to received knowledge. The first major contribution developed out of the fact that composition itself became an art form. *Musica poetica* came to signify more than the art of composition; it initiated a new kind of musical aesthetic defined by "secularism, sensuousness, and individual expression". (Lippman 1991: 19) I have already mentioned how this was directed towards a new understanding of how composers such as Dufay explored the way in which particular combinations of tones activated space, and how the debate over tuning and temperament surfaced as a spatial question in terms of musical perspective. Within the context of composition as art, the focus of Renaissance composers on the physical experience of tonality and how musical sound activated space in particular ways would become a significant feature of 20th century music and the emergence of sound art. It developed from the desire for a musical equivalent of visual perspective. The second major contribution arose when Leonardo, while investigating the nature of waves on water, drew the conclusion that sound behaves in the same way, anticipating much that was important to the subsequent study of sound. (Hunt 1978: 76)

## The Baroque Period

The end of the Renaissance and the beginning of the Baroque period in music is usually placed at the beginning of the 17th century. The middle class that arose from the Renaissance merchant families and the re-established importance of the church meant that liturgical, court appointed and independent entrepreneurial composers and musicians all played a role in European musical life and theory at the turn of the 17th century. (Carter 2006: 40)

Galileo and Kepler's work was controversial given the absolutist backdrop of their time. However, the 17th century set the tone for a new science of sound and music that built upon earlier experiment and also laid a formal foundation for experiment with the rise of the scientific academy. Descartes argued that truth can be attained purely through reason. Whereas human reactions to music are subjective and relative, the science of music and pure harmony is objective and governed by the laws of the universe. (Isacoff 2001: 244) This was reinforced in 1673 when William Noble and Thomas Pigot's experiments proved that each tone produced a series of overtones and that the resounding overtones of octaves, fifths and thirds were the purest tones of all. Thus, within the context of the science of sound, insofar as it related to music, the mathematical model of consonance prevailed, and equal temperament seemed less viable.

The fact is that, during the 17th century, surprisingly little was known about the physical properties of sound, yet there were many experiments attempting to understand these, most of which related to the speed of sound. The earliest of these experiments was conducted by Vincenzio Viviani and Giovanni Alfonso Borelli in 1656. Vivianni and Borelli stood on opposite sides of a valley and used gunfire to determine the speed of sound, working with the hypothesis that the speed of sound was either weak or strong and varied with wind speed and direction. (Hunt 1973: 102) Even though Viviani and Borelli's results were inaccurate, the fact remains that quantitative experiments were now being conducted in relation to sound.

Of great significance at this stage of our history is Francis Bacon's *New Atlantis*, the utopian novel that depicts a mythical island, Bensalem, discovered by accident by a crew of European sailors lost in the Pacific Ocean. Amongst other things the novel speaks of sound in a particularly telling way:

> We also have sound-houses, where we practice and demonstrate all sounds and their generation. We have harmony, which you have not, of quarter-sounds and lesser slides of sounds. Diverse instruments of music likewise to you unknown, some sweeter than any you have; with bells and rings that are dainty and sweet. We represent small sounds as great and deep, likewise great sounds extenuate and sharp; we make diverse trembling and warbling of sounds, which in their original are entire. We represent and imitate all articulate sounds and letters, and the voices and notes of beasts and birds. We have certain help which, set to the ear, do further the hearing greatly; we have also divers strange and artificial echoes, reflecting the voice many times, and, as it were, tossing it, and some that give back the voice louder than it came, some shriller and some deeper; yea, some rendering the voice, different in the letters or articulate sound from that they receive. We have all means to convey sounds in trunk pipes, in strange lines and distances.
>
> (Bacon 1627: 43)

Prior to any of the sound technology, which I will discuss later, Bacon's description is strikingly similar to the kind of sound world that electronic music eventually made possible. It is arguable that before this could happen a shift needed to occur in the way that sound was thought of. There are two important instances, often cited in the literature, that give us an insight into what sound meant during this period.

The first is Athanasius Kircher's *Musurgia Universalis* (1650), as well as *Phonurgia Nova* (1673). Whereas the former was a panoptic encyclopaedia of music and sound both historical and contemporary, both western and eastern, the latter focused particularly on sound. *Phonurgia Nova* illustrated Kircher's understanding of the behaviour of sound and the imaginative uses of this understanding. Even though the work describes the propagation of sound and how this applies to architectural space, its focus is on sound amplification and how a variety of horns not only amplify the voice when they are spoken into but also amplify the sound when listening.

The second is John Locke's *An Essay Concerning Human Understanding* (1689). Whereas Kircher demonstrated the physical attributes of sound, using the ear as instrument of inquiry, Locke questioned what the ear was experiencing to begin with. In brief, *The Causal Theory of Perception* draws a distinction between the perceived, which he calls "ideas", and the power to produce the perceived, which he calls "qualities". He then makes a distinction between primary and secondary qualities. Whereas primary qualities are inherent properties of the objects that give them the ability to be perceived, such as "bulk, figure, texture and motion", secondary qualities do not in themselves have the ability to cause us to perceive them but are dependent for this on primary qualities such as colour, odour and sound, for example. (Locke 2011: 216) For Locke, sounds are dependent on the primary qualities of that which makes the sound and the fact that we perceive a set of primary qualities as objects is dependent on ideas. Primary qualities, or capacities in the primary object, cause secondary qualities or experiences. What is relevant to our historical overview is that sounds are not considered by Locke to be objects in themselves. Although Bacon's "artificial echoes" is a striking premonition, it is arguably not until the advent of sound recording that sounds could be thought of as objects in their own right.

The music of the period seems to have isolated itself from the implications of the experimentation of Bacon, the acoustics of Kircher and the metaphysics of Locke and focused more on affect. Baroque music gave rise to opera and solo song, elaborate harmonic chords and dominant melody. (Greer & Lewis 2004: 441) What characterises Baroque music and what is perhaps seen as an overarching theme of the Baroque period, was ornamentation and embellishment (Neuman 1978:1), which, for the ruling elite and the church, was a means of expressing affluence, abundance and excess (Sadie 1990: 417), the kind of hedonism that is also evident in the Rococo painting of the time. Musical scores also became more specialised and music became intrinsically commodified and domesticated as musical "connoisseurship" flourished further. Printed music could not be communicated with the same effectiveness as hand-written music because printed music was uniform and the handwriting of the composer was part of the expressive content of the music, the results of which were two-fold. On the one hand, the composers would have to give more detailed instructions to their performers, giving rise to orchestration, and on the other, the broad public would not easily be able to perform the pieces, which gave the music a certain level of prestige. (Carter 2006: 48)

Stylistically, the vocal music of the Baroque period went through three phases. During the early Baroque, it was highly ornamental in its design and required great skill and abilities from the performer. The middle Baroque and thereafter is characterised by a reduction of ornament and the Italian idea of *bel canto* being favoured. In the latter part of the Baroque period, vocal ornamentation and embellishment flourished to a degree that was unheard of before, much to the disgust of many critics. (Rogers 1998: 351) The instruments of the Baroque period also evolved considerably in that those that were used during the Renaissance were being radically redesigned and many new instruments were being invented. Harps increased in size, higher notes began being composed for violins, which meant that the fingerboard was lengthened to accommodate this, the clavichord was generally accepted as the household keyboard for which Bach wrote 48 preludes and fugues and, finally, the woodwind instruments were redeveloped, most likely because of the changing fashions in the music of the late Baroque. (Montagu 1998: 366 – 372)

The Baroque period could be defined by a greater diversification of musical forms and instruments, but it also emphasised space as a composed element of music. This happened in three major ways. The first is by the rise of orchestration itself. Although there were precursors, such as the opera, oratorio and ballet, the ensembles for these forms were largely disorganised (Von Ahn Carse 2012: 1), and it is only during the

Baroque period that the art of orchestration was inaugurated. (Von Ahn Carse 2012: 33) Of course, grouping instruments into sections was about creating a greater magnitude of sound, but it also meant that conversations across space could be composed. In the simplest form the solo concerto places the soloist in the foreground and the orchestra in the background and implies a figure-ground relationship. More complex forms such as the concerto grosso became richer in their exploration of space. Vivaldi's *Concerto Grosso in D-Minor Op. 3 No. 11* (1711), for example, divides the orchestra into two sections, and as the composition unfolds the sound gradually sways from left to right to left continuously.

The second way that space became a composed element of music is through the development of terminology used to describe the manner in which musicians were instructed to play their instruments. Here, proximity could, in certain instances, be interpreted as being implied by amplitude and speed. *Piano* instructed the musician to play softly and *pianissimo* even softer; forte meant loud, *fortissimo* even louder. In general, *piano* and *forte* could be interpreted as spatial devices to imply nearness and farness. Speed was similar: *allegro* instructed the musician to play fast and *adagio* to play slowly. Notes played in quick succession have greater density and could be interpreted to imply nearness, but the same notes played slowly seem more distributed and imply distance. This is similar to the tonal gradient of a painting: objects in the foreground are near and objects in the background are watered down.

The third way in which space became a composed element in music was related to form. Of most significance here is the *sonata,* particularly because of the way it dealt with tonality. There are many varieties of *sonata* but in its most basic form, it is typically divided into two parts that take the listener on a journey through one musical space to another through a process of tonal transformation as the piece moves from one key into another. This is similar to the experience of Baroque architecture, where the contrast between design elements unfold through a visual narrative as one walks through the space. (Isacoff 2001: 302)

In conclusion, the diversification of musical sound during the Baroque period also appears to be an exploration of human sensibility. It is possible to reflect on this period in music as the sonic equivalent of Robert Burton's *Anatomy of Melancholy* (1621), a work in which the structure of musical sound is seen as less important than the emotions that it could elicit. Music became less rooted in number and religion. The harmonic arts and the sonorous bodies that they elicit were exploited as theatrical devices, resulting in the development of new musical forms, such as the sonata, that were vehicles for tonal narratives. Within this context, ornamentation was not only an expression of decadence and indulgence but also of virtuosity and expressive melody that, unlike the self-reliance that characterises the Renaissance, became a symbol of "longing and self-denial". (Apel 1974: 82) The transition from vocal to purely instrumental music that began with Bach meant that a new, self-referential language was being developed that was independent from the meaning of words, Joseph Haydn being its first master. (Tapper & Goetschius 2001: 240)

## The Classical Period

The end of the Baroque period and the beginning of the Classical period is commonly marked by the death of Bach and Handel during the mid-17$^{th}$ century and the dawn of the Enlightenment. Newton published his *Principia (Mathematical Principles of Natural Philosophy)* in 1687 – a work that, aided by mathematics and methodologically based on observation and experiment, worked out the nature of universal gravitational forces as well as the laws of mechanics, which I will discuss in more detail in Chapter 4. (Greer & Lewis 2004: 424). The scientific momentum of the previous century, most notably that of Newton, led intellectuals to believe that humanity, too, could be studied and improved through observation. (Burkholder et al. 2014: 463) Consequently, even though attempts were made to reconcile science and Christianity, faith in God assumed diminished importance in philosophy. In this context, Immanuel Kant drew from the rationality of Descartes and Locke's understanding of the experiential. The rational ideal of order, clarity, balance and emotional restraint is evident in the music of the classical period. (Locke 2011: 215-222)

The rise of the middle class also had profound effects on the musical landscape. There was a specialisation in instruments, new musical forms that focused on specific instruments and a widening sense of connoisseurship that was accompanied by an increase in the number of amateur musicians. In this context instrumental music took centre stage. Although many of the instruments of the Classical music period were already developed during preceding years, more emphasis was placed on specific instruments such as the piano and smaller ensembles such as the violin quartet and the self-contained brass section as the art of orchestration became more specialised. (Greer & Lewis 2004: 424) This generally was music of homophonic melody with accompaniment that had a clear division of parts. Thus, Classical music was more studious in its approach and seems have been more focused on formal investigations than emotion. This is reflected in forms such as the solo sonata, chamber music and the solo concerto, all of which presupposes a kind of interrogative and focused listening. The sonata (sounded) form itself became widely used and reflects the spirit of the emerging middle class that began to listen actively to music for its sonorous qualities. This changing social landscape and the effect it had on music also had spatial implications. On the one hand, music was becoming increasingly domesticated in the form of the home piano and forms of music such as chamber music. On the other hand, music became more of a catalyst for social cohesion, which is evident in the increasing popularity of outdoor concerts, the merging of national styles and the growth of the idea that music is a universal language. (Burkholder et al. 2014: 464)

As a result, the move towards instrumental music that was self-referential and universal is an important theoretical starting point for the way that Classical composers used non-musical sound. The point can be illustrated by looking at selective instances of the use of percussion in the work of Haydn, Mozart and Beethoven.

During the latter half of the 18th century composers increasingly began to make use of percussion instruments. The first of these was the timpani or kettledrum, which has a voluminous deep tone that is quite arresting, as is illustrated by Hayden's *Symphony No.103 in E-flat Major* (1795), or the *'Drumroll' Symphony*, where the piece is introduced by a sustained thunderous drumroll that sets a haunting tone for what proceeds. The percussion section also often made use of the explosive crashing of cymbals and the ringing metallic ping of a triangle. These three sounds were also used in different combinations that created new "composite sounds" (Stuckenschmidt 48: 1969), as in the case of Mozart's *The Abduction from the Seraglio* (1782) and Haydn's *Symphony #100 in G-Major* (1793). In both cases the percussionist strikes the side of the drum repeatedly, which adds a subtle rhythmic ticking sound. Even though the timpani and the triangle have a specific tonality, when accompanied by cymbals and the striking of the side of the drum these sounds seem more non-musical than musical.

It is possible that composers were influenced by military marches, where the drum functions as a pulsating measure of footsteps. This is evident in the way that percussion is frequently used in marches. Much of the music of Mozart, Haydn, Beethoven and others imitates Turkish *mehter* or janissary bands and this had a profound influence on the way percussion became used in orchestras at the time. (Bellman 1998: 45) Beethoven's *Turkish March Op. 113* (1811) is probably the best-known example of the emulation of janissary bands, where the string section refers to the sound of the zurna (an instrument similar to the oboe) and the cymbals mark the sharp contrasting patterns of the melody. At this point, percussion had become a full part of the orchestra, which resulted not only in the integration of sound that had previously been considered non-musical but is also one of the primary contributing factors for the expanded sonic vocabulary of twentieth century music.

Within the context of the instrumental music of the 18th century and the introduction of non-musical sound, the scientific understanding of sound also improved in terms of hearing and understanding the propagation of sound. Even though the term "Enlightenment" suggests that science was based on observation, which favoured the eye, hearing and sound became an object of study under the new scientific scrutiny. (Sterne 2003: 2). A prime example of the beginnings of this is provided by medicine through the invention of the stethoscope, which not only isolated and intensified sound but required a particular kind of listening: listening for sounds within the body in order to make medical judgments by means of auscultation. (Sterne 2003: 111) This meant, like Kircher's *Phonurgia Nova* (1673) mentioned earlier, that the ear, too, became an instrument for scientific inquiry. This echoes the way in which the sonata and chamber music was listened to with an inquiring ear.

Even though Newton (discussed specifically in Chapter 4) did in fact dedicate himself to the study of sound and attempted unsuccessfully to provide an accurate reading of the speed of sound, it is only in 1738 that Cassini de Thury solved the longstanding question when he accounted for the influence of temperature on speed. During the same period, the physicist Daniel Bernoulli (1700-1782) discovered that the tones produced by a vibrating string set in motion a series of residual tones that are inharmonious. As a result, the idea of mathematical consonance and tuning turned out to be incompatible with the actual behaviour of sound waves. (Beyer 1999: 14) The speed of sound and the relationship between pitch and tone meant that there was a scientific method for understanding that space was the medium of sound.

The music of the Classical period became more refined while listening became more of a scrutinising activity. There was a move towards an international style of music, underscored by the idea that music is a universal language. The tendency to introduce non-musical sound in the form of percussion began to gain momentum as the sonic vocabulary of music expanded. The science of sound reflected the new ways of listening with the advent of the stethoscope and a more accurate scientific understanding of the behaviour of sound.

## The Romantic Period

The Romantic period was characterised by, amongst other things, the art of setting literary works to music and, as a result, many of the stylistic innovations of the period are concerned with conveying emotions and moods. The clear distinction between compositional movements during the Classical period was unsuitable for the unfolding of the thematic content of the literary work and composers sought to, firstly, synthesise movements into a whole and secondly, blur the lines between word and tone. The former case is evident in the continuity between movements in Liszt's work and even more so in the Wagnerian *Gesamtkunstwerk*, which attempted to synthesise drama and music into a total work of art. Wagner also saw this as an answer to the way the division of labour divided art and placed certain art forms in subordinate positions to others. (Lewis 2016: 84) There was a renewed interest in older ideas such as the instrumental recitative, which during the Romantic period took the form of the tone poem.

Emotions and moods required a richer and more nuanced lexicon of sounds. This prompted composers such as Schumann to become more evocative in their chromatic colouring as well as more variable in the diversity of rhythms, such as in the case of Brahms. (Boyden 1973: 285) This move towards an expanded scope of sound was also supported by a new approach to instrumentation. Not only were old instruments being greatly improved upon, but many new instruments were introduced to the orchestra. This resulted in a wider register for woodwind instruments, the introduction of the English horn, the saxophone, the tuba, a side bass drum, bells, the celesta and xylophone, to name a few.

This rapid proliferation of new instruments and the widening range of their expressive capabilities were concretised in Hector Berlioz's *Treatise on Instrumentation*, first published in 1844. The text is important in its encyclopaedic detail of all orchestral instruments and their sonorous qualities, describing how to employ sounds to achieve certain effects as well as detailing how architectural space can be exploited to achieve better sounding orchestras. In Berlioz's writing on the understanding of instruments, their specialised tones and timbres, and the numerous ways in which they can be combined, one gets the sense that he believed any sound could be made by the orchestra. The way in which he thought of the orchestra as an encompassing vehicle for the expression of all sound, whether musical or noisy, and the power that these sounds wield, becomes clear in the final chapter:

> …the thousand combinations possible with the giant orchestra above described could produce a wealth of harmonies, a variety of sounds, an abundance of contrasts surpassing anything heretofore achieved in art. It could create, above all, an incalculable melodic, rhythmic and expressive power, a penetrating force of unparalleled strength, a miraculous sensitivity of gradations, in the whole or in any individual part. Its calm would be as majestic as an ocean in repose, its outbursts would recall tropical tempests, its explosive power the eruptions of volcanos. In it could be heard the plaints, the murmurings, the mysterious sound of primeval forests, the outcries, the prayers, the triumphant or mourning chants of people with an expansive soul, an ardent heart and fiery passions. But its crescendo would make even the most unyielding listener shudder; it would grow like a tremendous conflagration gradually setting the sky on fire.
>
> (Berlioz 1991: 989)

This kind of specialised encyclopaedic writing during the Romantic period also applied to the science of sound. Two other influential works that are important to mention are

John William Strutt's *The Theory of Sound* (1877) and Hermann von Helmholtz's *On the Sensation of Tone as a Physiological Basis for the Theory of Music* (1877). The former was a comprehensive work about the science of sound and how it behaves and was indispensable to the science of acoustics. The latter sought to explain exactly how we hear and how particular tones elicit specific responses.

Indeed, the Romanticism was one of many contrasting ideas about society where the struggle for individual freedom stood in opposition to the Industrial Revolution and the division of labour it had brought about. Perhaps, in confronting the rapid transformation of the environment, music and literature reacted by becoming more sentimental about the past. Setting this aside momentarily, in the move towards emotional expression, musical sound became more sophisticated and began to include non-musical sounds more readily. The technological advances also allowed instruments to become vastly improved, which further expanded the lexicon of orchestral sound. Lastly, literary works served as inspiration for concretising these new possibilities, helping to create a new understanding of sound and lay the foundation for the Modern period.

## The Modern Period and Noise

While a revolution in sound recording technology was under way during the 1870s, a shift in musical ideology was also in progress, with the late 19$^{th}$ and early 20$^{th}$ century generally referred to as the Modern period of music. At the turn of the century, the scale of the Mahler and Strauss orchestras had become even larger in an effort to move the audience in new emotional directions, but whereas some of Strauss' work, in Boyden's conservative view, sought to shock his audience, Mahler sought to explore the entire expanse of the human emotional universe. (Boyden 1973: 397) Furthermore, the short-lived, yet influential Impressionism of Debussy reconceived tonality as a mediator of moods and blurred sonorous atmospheres, as is evident in *Jeux* (1913).

By the beginning of the 20$^{th}$ century, the next generation of composers thought that the Romantic idiom had become overstated and revolted against it, with the aim of freeing tonality and rhythm. Most notably, Schönberg, Webern and Berg redefined tonality and advocated atonality, dissonance and unpredictable rhythms, the early signs of which are evident in Schönberg's *Pierrot Lunaire* (1912). Stravinsky, too, was equally subversive but not so much in terms of tonality, more so in terms of orchestration and rhythm, evident in *The Rite of Spring* (1913). Thus, the formal flexibility of Debussy, the harmonic explorations of Schönberg and the stark rhythmic contrasts of Stravinsky are all defining moments of the beginning of the Modern period in music. There were also two further factors that define the period: the theoretical implications of Schönberg's *Harmonielehre* (1911), with particular reference to the notions of *Klangfarbenmelodie* and *Sprechgesang*, and the notion of noise within the context of modernisation.

In the final chapter of *Harmonielehre*, Schönberg draws attention to the three constituent parts of musical sound, namely pitch, colour and volume, claiming that tone-colours (*Klangfarben*) are frequently overlooked. In essence, the distinction in texture between tones and the characteristic timbres of instruments point towards all the sonorous qualities of a tone apart from its pitch. In other words, a melody in the conventional sense would be written as a sequence of tones, but what Schönberg was proposing is that it is also a sequence of textures. In the context of *Klangfarbenmelodie*, the distinction between musical and non-musical sound seems to disintegrate. The vocabulary of composition is potentially all-encompassing, and anything could potentially be an instrument. *Klangfarben* apply to the voice in a similar way. Older notions such as *Sprechgesang* and *Sprechstimme* are invoked by Schönberg to draw attention to the non-musical aspects of speech as a composed element of singing.

It is not inconceivable that Stravinsky and Schönberg were implicitly responding to the mechanisation of the modern soundscape. This was certainly true for the painting of the Cubists and Futurists. Umberto Boccioni's *La Strada Entra Nella Casa* (The Street Enters the House) (1912) illustrates this in colour and composition (Figure: 2). The ethereal blues and lilacs contrast with the austere discordant reds and yellows, the noise invades the balcony and the room. As the fractured picture plain disrupts the viewer's line of sight, so too do the polyphonic and polyrhythmic disrupt the continuity of listening. The ear is continuously leaping between melodies accentuated by unexpected rhythmic dissimilarities. Extreme dissonance and intricate rhythm allude to the modern condition by transcribing the aural life of the urban environment. Speaking about

Stravinsky's *The Rite of Spring*, T.S. Eliot says:

> [The music seemed to] transform the rhythm of the steppes into the scream of the motor-horn, the rattle of machinery, the grind of wheels, the beating of iron and steel, the roar of the underground railway and other barbaric noises of modern life.
>
> (Eliot, quoted in Albright 2004: 11)

**FIGURE 2: Boccioni, U. *La Strada Entra Nella Casa.* (1911)**

Early Modernism also embraced the mechanisation of society and this became evident in the music of the time, which was gradually beginning to incorporate fragments drawn from the mechanised urban soundscape. If the formal aspects of Stravinsky and Schönberg allude to the discontinuous and fragmentary soundscape of the early 20th century, then calling into question the fragment itself became a means to emphasise the aural experience of the modern condition. Satie's *Parade* (1917), for example, was composed for string, brass and wind instruments and called for the inclusion of typewriters, sirens, lottery wheels, airplane propellers and other noise instruments. (Nicholls 2004: 216) Milhaud's *L'Homme et son désir* (The Man and his Desire) (1917) included various percussion elements as well as a whip and a whistle and Antheil's score for the film *Ballet Mécanique* (1924) included piano players, electric bells and airplane propellers. Picasso's *Still Life with Chair Caning* (1912) is perhaps the earliest visual equivalent. Not only is the wholeness of the subject disrupted by a series of simultaneous viewpoints, but the collaged fragment of the imitation chair caning is a symbol for industry and the materiality of mass production. The sound of the lottery wheel or typewriter, for example, performs a similar function: they are readymade fragments that make audible mechanisation, mass production and speed. (Banash 2013: 49) Gershwin reinforces this:

> The machine age has influenced practically everything. I do not mean only music but everything from the arts to finance. The machine has not affected our age in form as much as in tempo, speed and sound.
>
> (Gershwin, quoted in Albright 2004: 386)

If composers such as Satie, Varèse and Antheil drew our attention to the mechanical soundscape by cutting and pasting elements from it into their compositions, then the aural sensibility of the Futurists paid attention to the materiality of the mechanised soundscape. This required that they abandon traditional instruments altogether. Italian Futurism itself was initially a literary movement inaugurated by Marinetti's *Futurist Manifesto* (1909) and although spreading rapidly throughout the arts, it left music relatively untouched until in 1910 when Balilla Pratella published the *Manifesto of Futurist Musicians*. Pratella was fundamentally concerned with a rejection of the musical establishment by formulating a set of "irrevocable conclusions" such as:

1. The liberation of individual sensibility from all imitation or influences of the past, feeling and singing with the spirit open to the future, drawing inspiration and aesthetics from nature, through all human and extra-human phenomena present in it. Exalting the man-symbol everlastingly renewed by the varied aspects of modern life and its infinity of intimate relationships with nature.

2. To destroy the prejudice for ‘well-made’ music – rhetoric and impotence – to proclaim the unique concept of Futurist music, as completely different from the music to date, and so to shape in Italy a Futurist musical taste, destroying doctrinaire, academic and soporific values, declaring the phase ‘let us return to the old masters’ to be hateful, stupid and vile.

(Pratella 1973: 37)

The phrases “spirit open to the future” and “prejudice for well-made music” place this well within the domain of Modernist ideology, although the manifestations within Italian Futurist musical practice did not occur with the same ferocity as it did in its literature. With reference to Skriabin’s “music of colours”, Bruno Corra composed *Abstract Cinema – Chromatic Music* (1912) which was concerned with the relationship between tonal colour and visual effect but did not really reflect the rebellious spirit of Pratella. However, Luigi Russolo took the task to heart when in 1913 he wrote *The Art of Noises* and created an orchestra of noises.

The manifesto itself was written as a letter to Pratella and begins by contrasting the silence of ancient life with modern life, the machine and the birth of noise. Russolo then charts the evolution of sound and contextualises his age, stating that sonic explorations through dissonance and “harsh sound” bring his generation closer to “noise-sound” which he believes runs parallel to the development of machines. He proclaims that the conventional orchestra and its four varieties of instruments are not equipped for the creation of noise-sound. While attentive to the nature of the soundscape of modern life, Russolo reminds Pratella that the Futurist ear is more inclined to find enjoyment in “the combination of the noises of trams, backfiring motors, carriages and brawling crowds than in rehearsing, for example the ‘Eroica’ or the ‘Pastoral’”. (Russolo 1973: 76) The “combination of noises” then becomes the foundation of the manifesto and a primary point of departure for Futurist acoustic and compositional exploration. The manifesto was written before Russolo built his *ululatori* (howlers), *rumbatori* (roarers), *stropicciatori* (rubbers), *gorgoliatori* (gurglers) and other instruments of his noise orchestra as an expression of his formulated noise categories below:

1. Rumbles, roars, explosions, crashes, slashes and booms.
2. Whistles, hisses and snorts.
3. Whispers, murmurs, mumbles, grumbles and gurgles.

4. Screeches, creaks, rustles, buzzes, crackles and scrapes.
5. Noises obtained by percussion on metal, wood, skin, stone, terracotta, etc.
6. Voices of animals and men: shouts, screams, groans, shrieks, howls, laughs, wheezes and sobs.

(Russolo 1973: 74 – 88)

It is immediately evident that Russolo is attempting to eliminate tonality altogether. The tonal qualities of sound are filtered out and what remains is its graininess, its harshness, the soundscape of ear-piercing cacophony. Russolo then uses this topology as a template for the design of new noise instruments.

Russolo's performances were never recorded. However, the score for the 1913 performance *Risveglio di una città* (The Awakening of the City*)* still exists in fragmentary form. Some pictures and concert reports survive as well as original and rebuilt *intonarumori* (noise instruments). (Nicholls 2004: 216) Russolo's impact was extensive, and he influenced a future generation of composers and artists alike. The Dadaists, who already had an element of noise present in their happenings and "crazy cabarets", immediately come to mind. More specifically, in the same year of Russolo's noise music, Duchamp randomly pulled notes out of a hat as a chance procedure in the composition of *Musical Erratum* (1913), and in 1924 Tzara asked of musicians to smash their instruments. The raucous orchestras of the Futurists sought to abolish traditional instruments and magnify the noises emanating from the soundscape of a rapidly mechanising environment. True, these sounds were becoming more commonplace and more numerous but for Varèse and Antheil, they were not new and thus they sought to generate sounds that were unheard before.

*Ameriques* was the first of Varèse's compositions of the period, written between 1918 and 1921 and including noises such as a steamboat whistle, a rattle and a whip. *Offrandes* was the first work of his to be premiered in New York on the 23rd of April 1922. It was hardly controversial, written for a soprano and a small orchestral accompaniment largely comprised of percussion instruments, and received little critical attention. (Oja 2000: 33) In the following year, *Hyperprism,* a small chamber piece for brass, woodwinds, percussion and a siren, premiered with the same modest reception. It was only upon its debut in Philadelphia on the 7th of November 1924, and then in New York on the 16th of December, and primarily because Leopold Stokowski conducted the piece, that Varèse became a more recognised figure. (Oja 2000: 34-35) Paul Rosenfeld consistently wrote about Varèse using mechanical metaphors that were closely related to American urban life. Varèse's compositional pursuits were embedded in his disillusionment with traditional instruments as he found them largely inadequate. He thought that the noises the Futurists created were mere reproductions of everyday noises and dreamed of new sounds played by new instruments. (Bijsterveld 2008: 145)

Similar sentiments about the Futurists were shared by painter Piet Mondrian and composer George Antheil. Mondrian's *neoplasticism* rejected the aesthetic qualities of the plastic arts, painting and sculpture, that imitated nature by producing "round, physical, bowed, closed" shapes (Bijsterveld 2008: 145) in favour of abstraction, exactness, straight lines and primary colours. Based on this preliminary ideal he criticised the Futurists for using sounds from nature, noise instruments that still produced diatonic and chromatic tones and compositions that were still based on repetition. Mondrian therefore proposed instruments that played themselves such as electronic instruments, magnetic instruments and automata, instruments that were capable of making a sudden and sharp tonal deviation. He drew parallels between speed in music and straight lines, between colour (red, yellow and blue), not-colour (black, white and grey) and tone (sound) and not-tone (noise). (Bijsterveld 2002 2008:146-147) Antheil also drew comparisons between image and music, calling his scores "time canvases", as illustrated by his use of "*decoupage* [that] depends on new strategies for nontonal discriminations of figure from ground". (Albright 2000: 230) More importantly, Antheil was interested in time and although Varèse's *Ionisation* (1933) was technically the first all-percussion ensemble performance, Antheil's score for the film *Ballet Mécanique* (1924), which included repetition, the simulation of noise and tactful use of silence, was realised through the use of percussion scoring techniques with the aim of revealing the time principle of music as more important than the tonal principle. (Albright 2000: 236)

Indeed, Varèse's search for new sound and Antheil's percussive *decoupage* were to reach their full maturity in parallel with the technological developments in relation to sound. At the time, even the phonograph and gramophone were perceived as having real potential as musical instruments, particularly because of their ability to create, or rather reproduce, “any tone-colour or rhythm, even ones that were non-existent in modern orchestras”. (Bijsterveld 2008: 152) The first known gramophone performance of this kind was Stefan Wolpe’s Dada event in 1920. Wolpe later recalled:

> I had eight gramophones, record players, at my disposal. And these were lovely record players because one could regulate their speed. Here you only have certain speeds – seventy-four [*sic*] and so on – but there you could play a Beethoven symphony very, very slow, and very quick at the same time that you could mix it with a popular tune. You could have a waltz, then you could have a funeral march. So I put things together in what one might call today a multifocal way.
> (Wolpe, quoted in Scheinberg 2001: 61)

The performance predates Respighi’s *Pini di Roma* (1924), a composition for orchestra and gramophone, the three lost studies entitled *Grammophonmusik* (Gramaphone Music) (1929) by Hindemith and Toch and John Cage’s *Imaginary Landscape No 1* (1939), all of which explored the use of the gramophone and phonograph as orchestral instruments. The performance was fundamentally intended to be ephemeral and throughout Wolpe’s career he tended to foreground the importance of the process rather than creating finished products. The idea of the “multifocal” that was widely explored by artists of the early 20th century, such as the Cubists, who endeavoured to represent simultaneous viewpoints, was also evident in new modes of communication that “emphasised collapsing distances and temporal simultaneities”. (Scheinberg 2008: 65) Wolpe’s performance is an expression of the experience of modern life, seemingly synchronic until its eventual collapse, slowing down, speeding up into a mismatched mangle. The Hungarian painter, photographer and Bauhaus School professor László Moholy-Nagy also believed in the potential of the phonograph as instrument, although he took an entirely different approach to that of Wolpe and others. Moholy-Nagy proposed that the phonograph become an instrument of production rather than reproduction and proceeded to create a number of “etchings” on the surface of the wax plate itself in 1922, incising graphic patterns as a means of notation that he called the “groove-script”. (Moholy-Nagy, quoted in Cox 2004: 80)

The 1920s was also an era of technical innovation in relation to sound recording technology, in particular the electrification of recording and the development of the microphone. Before the 1920s, recordings were made by mechanical means and microphones were little more than horn-shaped tubes. The resulting recordings were poor in comparison to electrified recording, given the greater degree of amplitude control that electronic recording allowed. (Chanan 1995: 56) Although this was of great significance, the degree of manipulability was still limited and within the domain of recording companies. It was not until the 1950s that the slow but steady development of tape recording would initiate the true democratisation of better-quality sound recording. I will look at sound recording and playback in more detail in Chapter 3.

The music of the early 20th century embraced noise. This begins with the dissonance and discontinuity of Schönberg and Stravinsky. Schönberg's idea of *Klangfarbenmelodie* (sound-colour melody) imagined a new hierarchy of musical sound based on the textural over the tonal. Notably, discontinuity and dissonance were ways of implicitly referring to the soundscape of modernity and collage and the fragment was a way of overtly referring to mass production, mechanisation and speed. Thereafter, a complete rejection of tonality and tradition was brought about when the Futurists sought new sound through a veneration of noise. Varèse and Antheil refuted the Futurist's claim to new sound and recognised that the answer to the production of new sound lay in new sound technology and how early experiments by Wolpe introduced a new narrative of experimentation through technology. The next section will deal more specifically with sound technology and experimentation

## The Rise of Electronic Music and *Musique Concrète*

Along with the sound recording industry and radio, another important technological advancement in relation to sound came to fruition as a result of World War II: magnetic tape recording. Even though the development of magnetic recording technology was slow and overshadowed by the phonograph, in 1927 J.A. O'Neill patented paper tape coated with a magnetic liquid while, at the same time, German Fritz Pfleumer was working on the formula for a metallic oxide that would adhere to paper. The advantage of paper magnetic tape was that it was inexpensive and easy to edit by cutting or "splicing". When the Magnetophon K-1 was presented at the Broadcast Exhibition in Berlin in 1935, it was perceived to be useful as a dictation device for pilots given the wartime context. Tape recording eventually became commercially available in the early 1950s and began competing with the phonograph.

There was a general cultural and creative revival after World War II and the technical developments that were, at times, a direct result of the war, provided artists and composers with tools to create and explore sound in new ways. The reel-to-reel tape recorder was at the forefront of this exploration. Not only did it provide its user with the ability to manipulate sound, it was relatively easy and inexpensive to use. In this respect, there were three paths of creative exploration that all centred around magnetic tape recorders and emerged in the early 1950s. These three schools not only had institutional support but also a particular ideological underpinning and were 1) the Paris group, 2) the Cologne group and 3) sound laboratories in and beyond Europe, to which I will refer as the "free use group". What is perhaps the characteristic feature of the post-war period is a move away from traditional means of composition towards experimentation with sound in a "sound laboratory". Inasmuch as the compositions can be interpreted as pieces of music, they can also be interpreted as the results of experiment. In this sense, the composer was in equal measure a scientist, and engineer and an acoustician.

The Paris group was formed by Pierre Schaeffer, initially an apprentice at the Radiodiffusion Télévision Française in the 1930s, where he was eventually employed as an electronic engineer. In 1942, he persuaded the RTF to form a "studio" for the research of "the science of musical acoustics with himself as director". (Manning 2004: 20) This venture came to fruition in 1946 and was known as Club d'Essai. Schaeffer's primary goal, through experimentation, was the search for new sound by using "real-life acoustic sounds" or *Musique Concrète* (Schwarts & Godfrey 1993: 115). In doing so, he began conducting experiments using percussion sounds. His experimentation with these sounds led him to conclude that a single sonic event is characterised by attack and decay, and not only by timbre. Schaeffer went on to pioneer many studio compositional techniques such as montage, reverse playback, variable speed playback, continuous tape loops, intercutting or "splicing" and spatial location. His first work, *Étude aux chemins de fer* (Study of the Railway Lines, 1948) was composed using recordings from the Paris train depot Gare Des Batignolles. It is primarily composed using sequencing and tape loops and includes the sound of steam engines, train whistles and wagons passing over the railway tracks. Upon initial listening, the work seems to be a study in mechanical sound and the intersection of old and new. However; through the use of continuous loops the sounds become contemplative, meditative; recognising it as an everyday sound is of secondary importance.

After *Étude aux chemins de fer* Schaeffer began a number of experiments with traditional orchestral instruments, resulting in a number of short *Études* such as *Étude pour piano et orchestre* (1948), which consisted of various recordings of different orchestra instruments in the process of being tuned, accompanied by the piano improvisation of Jean-Jacques Grunenwald. Along similar lines he experimented exclusively with the piano in *Étude au Piano I* and *Étude au Piano II* and departed from traditional instrumentation altogether in *Étude aux Casseroles* - a study of pots and pans. These works, from the latter part of 1948, were all presented in a radio broadcast on the 5th of October 1948 under the title *Concert de bruits* (Concert of Noises) and were met with mixed reviews. Hardly discouraged, the following year Schaeffer convinced the RTF of the need for studio assistants and appointed the composer Pierre Henry and studio engineer Jacques Poulin. On March 5th 1950, the collective presented their work in a live performance at the École Normale de Musique, the group's first opportunity to experiment with the acoustics of a concert hall in which they used various turntables, loudspeakers and mixing units, and created live montages. (Manning 2004: 21-24)

In understanding Schaeffer's *Musique Concrète*, it is important to take note of its fundamental premise, namely *acousmatic listening*. The word acousmatic is derived from the Greek *akousmatikoi*, *akousma* meaning "oral saying" and *mathematekoi*, which is not necessarily associated with mathematics but rather with "learning or study". The two concepts combined results in *akousmatikoi*, which roughly denotes "listeners". (McKirahan 1994: 89) The word dates to Pythagoras and illustrates how he taught from behind a curtain, his disciples unable to see him but able to hear him. This was coupled with Edmund Husserl's phenomenology, which quite briefly "attempts to simply describe the content of experience without reference to its source or subjective mode". (Cox 2004: 76) This was an attractive proposition to Schaeffer and his work with sound, especially because tape recording allowed him to remove sounds from their source and work with them in a variety of new ways. This led him to think of his recorded sounds as sound objects, which he formally presented in his 1966 book *Traité des objets musicaux* (Treatise on Musical Objects). Schaeffer also coined the concept "listening without seeing", according to which the sound objects, separate from the source of their making, are reduced to their primary form as frequencies, tones, duration etc. (Schaeffer, quoted in Cox: 2004: 77) The simplest possible way to imagine acousmatic listening is to think of Foley artists, the name for artists producing sound effects for radio drama. Slowly crushing a pile of dried leaves, for example, could be done to represent the sound of rain. The sounds are so similar that the average listener would not notice the difference because they are listening without seeing.

Importantly, stereophonic sound, which had first been demonstrated in rudimentary form at the Paris Exposition in 1881, became the subject of many journal discussions in the 1920s as a means of overcoming the artificiality of playback. Then, in the 1930s, Alan Blumlein recorded a stereophonic version of Mozart's *Jupiter*. However, it was not until the early 1950s that stereophonic tape recording and playback became commercially available and only in 1958 that long-playing records were developed to play stereophonic sound. (Symes 2004: 75) The four-channel quadraphonic system was only developed in the 1970s. (Symes 2004: 77) The development of technology in relation to the spatialisation of sound is a testament to the advanced techniques of *Musique Concrète* productions. Poulin was particularly interested in the distribution of sound throughout the auditorium and had already developed a multichannel sound projection device using tape, known as a *potentiométre d'espace,* in the early 1950s. Although little is known about this invention, it is said to have been a device for the exploration of spatial projections of sound by placing two speakers in the front of the auditorium, one speaker overhead and another behind the audience, in the centre of the rear wall. (Manning 2004: 26)

There was a distinct aesthetic and intellectual difference between Schaeffer's *Musique Concrète*, whose primary concern was the use of real-life acoustic sounds, and the Cologne School, which believed that the only meaningful pursuit of sound was through the generation of electronic sound by artificial means. (Schwarts & Godfrey 1993: 115) Headed by music theorist, composer, critic and radio producer Herbert Eimert, sound engineer Robert Beyer and his collaborator Werner Meyer-Eppler, the studio was established for the West German Radio (NWDR) on the 18th of October 1951. (Holmes 2002: 100) While Meyer-Eppel had already written about the technological developments of sound in his 1949 paper entitled "Elektrische Klangerzeugung" (The Electrical Production of Sound) and together with Beyer collaborated on a series of lectures where they coined the term "Elektronische Musik", Eimert's motivation for the establishment of the studio was initially as a means of furthering Weberian Serialism. (Holmes 2002: 100)

Developed for experimentation with synthesised sound for composition, the Cologne studio had state-of-the-art equipment designed for this purpose. The German-American inventor Herald Bode, at a time when resources and materials were at a shortage, disassembled the melodium (1938), his earlier invention, and reconstructed it into the melochord (1941). The melodium was essentially an electronic organ with pressure sensitive keys and featured a pedal for vibrato control and a tuning transposition knob. The melochord had more features for controlling the synthesised sound and this is why Bode was commissioned by the Cologne studio to build a version of the melochord for them. (Bush & Kassel 2006: 71) The German inventor Friedrich Trautwein was also commissioned to build an updated monophonic trautonium, which was basically an electronic monochord with fret designations that indicated finger placement. (Holmes 2002: 101) At its peak, with Fritz Enkel as engineer, the Cologne studio had the latest in electronic instruments as well as audio oscillators that generated sine and sawtooth waveforms, various audio filters, a ring modulator, a white noise generator and, importantly, a variable speed tape recorder as well as a four-track tape recorder. (Holmes 2002: 102-103)

The Cologne school consistently theorised about their studio activities and, to a great extent, provided the theoretical backdrop for the future of electronic music. Initially they were very optimistic about the potential of electronic sound and its ability to be completely malleable ("Electronic music compels us to assemble each note as we require it" [Boulez, quoted in Roads 2004: 71]), often referring to the minute sound particles that they were able to create as sound atoms: "the next step might be the splitting of the atom (that is, the sine tone)". (Krenek, quoted in Roads 2004: 71)

Furthermore, Eimert and Meyer-Eppel produced preliminary qualifications as to the degree to which electronic instrumentation was applicable to the broader domain of electronic sound or music, proposing classifications and terminological elucidations (summarised below). These lead us to the conception that for the first time, sound production was possible within a "malleable continuum of every known and unknown, every conceivable and possible sound". (Wörner 1973: 123) Whereas Eimert defines the basic building blocks for the production of any conceivable sound, Meyer-Eppel sees the potential of electronic sound production within the context of music, Wörner summarises each:

Eimert:

> 1. Note – the pure tone (sine wave tone), free of overtones, which never appears in traditional music (or in nature). It issues from the production of sound. The sinusoidal tone system must therefore simply be a system of virtual relationships from which the composer can create structures in the form of series, relationships, rows and other form of organisation.
> 2. Sound – constituted of a succession of harmonic partials (sine-wave oscillations). In electronic music the components of partials can be varied.
> 3. Note mixture – frequencies of partials not harmonically related to the fundamental. Mixtures are always mixtures of sine wave tones (hence not the same things as chords); they have a higher degree of fusion than do sound complexes and can become 'sound' in a far more unified way than instrumentally produced chords. Stationary note mixtures can be realised effortlessly in electronic music.
> 4. Noise – determined by its specific character and breadth of its frequency range. The pitches of coloured noises are, in musical terms, the equivalent of approximately defined registers. Only 'white noise', filling the whole audible frequency range (comparable to white light), lacks any definition in terms of register.
> 5. Sound complex – two simultaneous different sounds (where more than two, there will be a chord). Between the sound and the sound complex comes the note mixture with its degrees of fusion – a novel feature. Sounds and mixtures can be electronically 'composed' in accordance with a predetermined compositional plan of organisation.
>
> (Wörner 1973: 122)

Meyer-Eppel:

1. Electronic instruments can be used in imitating the sound of conventional instruments
2. The second category of uses for electronic instruments concerns those designed so as to be characteristic and individual-sounding instruments for use in conjunction with traditional instruments.
3. Electronic instruments might also assume a solo status whether in serious and light music or as an expedient to serve as background music in broadcasting (radio plays), stage or films.
4. A fourth possibility consists in the combination of several electronic instruments in an ensemble.
5. The fifth is the autonomous use of electronic instruments.

(Wörner 1973: 121-122)

Eimert and Meyer Eppel clearly believed in the unlimited potential of electronic sound. For Eimert, this meant that anything audible could be synthesised in the sound laboratory, and Meyer-Eppel believed this to be an inexhaustible resource for music. The development of sound technology had reached a point where the search for new sound as a consequence of experiment had finally unlocked the DNA of auditory phenomena. Meyer-Eppel and Eimert initiated a process of defining a musical movement that manifested itself through the science of electronic sound and the mathematics of music and their language of experiment and composition was particularly evident in the Cologne school. One of the most influential composers to emerge from the school was Karlheinz Stockhausen.

Stockhausen studied music at the Hochschule für Musik Köln and the University of Cologne and continued his work under Olivier Messiaen in Paris and Meyer-Eppel in Bonn. Interestingly, Stockhausen worked at the Radiodiffusion Télévision Française with Schaeffer where he composed *Konkret Etüde* (Concrete Study) (1952) but soon thereafter he rejected the principles of *Musique Concrète* and began work at the Cologne studio in 1953, where he produced some of his most important work, such as *Gesang der Jünglinge* (Song of the Youths) (1956), *Kontakte* (1959-1960) and *Hymnen* (Anthems) (1966-1967).

Highly analytical and meticulous in his approach, Stockhausen's early work at the Cologne studio was based on the mathematical relationships of sine wave tones and timbres, using the serial technique to demarcate the compositional framework and hence the order and duration of the tones as he edited them using tape. This was evident in *Studie I* (1953) and *Studie II* (1953). (Holmes 2002: 65) During this early experimental stage, Stockhausen was also interested in noise and the ability for electronic instruments to render noise by superimposing sounds in such a way that the waveform density became so dense that the resulting form is *perceived* as noise. (Wörner 1973: 126) Unlike many electronic composers of the time, Stockhausen did not always produce purely electronic music. *Gesang der Jünglinge* (1956) for example, was an exploration of voice and electronic sound. Based on Daniel 3, a biblical parable about three boys in a fiery furnace, Stockhausen used the recording of a soprano boy singing the verse and mixed it freely with electronic sounds to the point that, at times, the two become almost indistinguishable. (Randel 1996: 871)

Stockhausen was also interested in spatiality and acoustic space as a medium. He experimented with orchestra and speaker placement in the concert hall, the movement of sounds across speakers and the movement of musicians while playing. Wörner explains how the sound-space relation in music was not new but that the traditional orchestra placement in space is to a large degree an invention of the 20th century. He cites numerous examples of how the use of space was developed over time, describing how echo as well as the use of chromaticism became prominent in the vocal and choral music of the 1500s. During the Baroque period multiple choirs were used. The Roman *Orazio Benevoli Festival Mass* (1628) manifested the sound-space relation on a grand scale, and Heinrich Schütz's *Symphoniae Sacrae III* (Sacred Symphony III) (1650), for three choruses, orchestra and organ, made use of spatial effects on a more intimate scale. According to Wörner, the use of space, where the orchestra and choir engage in dialogue, or were stationed in different areas of the concert hall, and the particular effects that are at the composer's disposal as a result of this, was wide-spread throughout the 17th and 18th century. More recently, Schönberg's unrealised interlude *Jacobsleiter* (Jacob's Ladder) called for four distant orchestras that would later join the main orchestra. In addition, the distant orchestras were to be transmitted through loudspeakers placed at various positions in the concert hall. In the 20th century the sound-space relation was widely used particularly for the purpose of theatricality, but the extent to which Stockhausen expanded upon this idea was unparalleled. (Wörner 1973: 155-159)

Stockhausen dreamed of new concert halls for new music where listeners are immersed in sound from all directions and are located in the so-called globular listening area. While in the process of composing *Gruppen* (Groups) (1955-1957) for three orchestras and *Carré* (Square) (1959-1960) for four orchestras and four choirs, Stockhausen envisaged some of the practical considerations of the new concert hall and proposed the following:

> 1. A spherical, circular or quadratic area such as will facilitate orchestral positioning at any desired place around the audience and/or in the middle of the audience.
> 2. No permanent platform; instead, a large number of moveable daises.
> 3. Parts of the floor at variable elevations.
> 4. Seating arrangements to be altered at will; no fixed seating. (spacing)
> 5. Fixtures for loudspeakers and microphones around the walls and in the ceiling.
> 6. Alcoves and/or balconies at different levels for small instrumental groups.
> 7. Doors not interfering with any circular disposition of orchestral groups around the walls (as many doors as possible distributed evenly round a circular area).
> 8. Electronically controlled echo that can be matched to suit any condition of performance.
> 9. A studio outside the hall for relaying over loudspeakers and for recording.
> 10. Separate lighting for the hall and for portable music-stand lamps.
>
> (Stockhausen, quoted in Wörner 1977: 161)

A similar rejection of spatial norms took place in theatre. An early example is Erwin Piscator's stage design for Ernst Toller's play *Hoppla, wir leben!* (Hoppla, We're Alive) (1927), which is a multi-level set where the action unfolds in eight separate areas. (Minden 1988: 302) Walter Gropius, founder of the Bauhaus School (1919-1933), theorised about resolving the distance between art and craft, the performer and the audience, the subject and the art and the artist and technology. "In the totalising project of art, object-making, music-making, and building would form a singular modernist unity". (Suderburg 2000: 6) Dessau Bauhaus, in particular, was interested in the resolution of certain polarities that pertained to humanity. In an attempt to reconcile the polarities between intellectual life and emotional life, the Dessau school saw theatre as a three-dimensional microcosm of the world and ideal for testing the fusion of opposing forces. This thinking was evident in Gropius's plan for a "Total Theatre", Andor Weininger's "Spherical Theatre" and Farkas Molnár's "U-Theatre"'. (Forgács 1995: 142) Although *Gruppen*, *Carré* and *Gesang der Jünglinge* explored the effect of sound in space where orchestra, choir and loudspeaker are placed to create a Bauhaus-esque immersive experience, Stockhausen's concert hall envisioned a kind of malleable environment, a music building, a building for music and in *Musik für ein Haus* (1965), music for a building.

Stockhausen's use of space draws a link between how Eimert believed that any conceivable sound could be synthesised and Meyer-Eppel's belief that this was particularly applicable to music. For Stockhausen, the orchestration of space was a consequence of the physical disposition of the sounds themselves and how they react to a given environment. Thus, the proposal for a music hall with multiple spaces, *centrally controlled*, suggests that space was not only the medium through which sound occurs but is as much an instrument as any other in the orchestra that could be precisely controlled. Stockhausen made many proposals for musical spaces, such as suspending the listener in an enclosed globular space, with the music coming from all directions.

Whereas the Paris studio used real-life acoustic sounds and the Cologne school dedicated themselves to the synthesis of sounds, at a range of other studios the ideologically influenced search for new sounds was less prominent than artistic or compositional preferences. There was a free mixture between synthesised and real-life sound. The most prolific studio of this kind at the time was the Milan Studio.

Founded by the Radio Audizioni Italiane (RAI) in 1955 and directed by Lucio Berio and Bruno Maderna, under the engineering supervision of Marino Zuccheri, the Studio di Fonologio Musicale was arguably the best equipped of its time as a result of its open-minded approach to music and experiment. Berio explains: "Bruno and I immediately agreed that our work should not be directed in a systematic way, either toward recording acoustic sounds or toward a systematic serialism based on discrete pitches". (Berio, quoted in Holmes 2008: 69) Berio's solo tape pieces between 1955 and 1961 reflect this, combining "vocal sound families and interrelated electronic sounds". (Berio 2006: 18) *Thema – Omaggio a Joyce* (Tribute to Joyce) (1958) and *Visage*

(Face) (1961) are emblematic of the free use approach.

*Thema – Omaggio a Joyce* (1958) was based on the opening passage of chapter 11 of James Joyce's *Ulysses* (1922). Berio recorded his wife, the mezzo-soprano Cathy Berberian's, recital of the passage and transformed it into a dynamic abstraction of streams of speech, mixed with flickering and pulsating electronic sounds capturing the essence of the opening of the passage which itself is reminiscent of instruments being tuned. *Visage* (1961) was Berio's last piece made at the Milan studio and also makes use of Berberian's voice. It comprises her saying the single word "Parole", mixed with various illegible utterances and electronic sounds. (Holmes 2008: 70-71)

The three-abovementioned studios had a great influence on the rest of Europe, as well as on the international musical community. Soon, many new studios were emerging. Otto Leuning and Vladamir Ussachevsky's studio, for example, further established the electronic music tradition in the United States. The pair collaborated in the early 1950s on their first work *Incantations* (1953) and presented it at Radiodiffusion Télévision Française. They were fundamentally interested in recording musical instruments and manipulating the recordings in various ways in the studio, as evident in works such as *A Poem in Cycles and Bells* (1954). Leuning recalls:

> We had the choice of working with natural and "non-musical" sounds like subway noise and sneezes and coughs or widening the sound spectrum of existing instruments and bringing out new resonances from the existing world of instruments and voices. We chose the latter.
>
> (Leuning, quoted in Holmes 2008: 91)

They quickly gained much notoriety in New York in the 1950s, composing several short works for Leopold Stokowski's concert held at the Museum of Modern Art, the 'score' for Orson Welles's theatre production of *King Lear* (1956) and the soundtrack for Alfred Hitchcock's movie *To Catch a Thief* (1955). Finally, together with Milton Babbit and Roger Sessions they established the Columbia-Princeton Electronic Music Centre in 1959 with funding from the Rockefeller Foundation. In the same year, the University of Toronto Electronic Music Studio under the directorship of Myron Schaeffer was established and in 1962, the Yale Electronic Music Studio opened under the guidance of Mel Powell. (Holmes 2008: 91)

In 1950s Britain, the rich tradition of radio drama with classical accompaniment was beginning to prove itself a fertile environment for the exploration of new techniques and devices used in the production of *Elektronische Musik* and *Musique Concrète*. Amongst others, Tristam Cary's *Japanese Fisherman* (1955) was one of the first radio dramas to fully incorporate the new sound, using the "cut and paste" technique and produced entirely without institutional support. (Niebur 2010:17) Although the piece was met with disapproval and disregarded as mere novelty, the door to further experiments was nonetheless opened. The BBC music department was reluctant to establish a studio for electronic music, viewing it as a threat to their imperative of educating people about Classical music. (Niebur 2010: 39) Regardless of all the opposition, with public demand and institutional backing from senior studio manager Desmond Briscoe and music studio manager Daphne Oram, the Radiophonic Workshop was formed in 1956 and premiered with their first experimental radio broadcast of works such as Giles Cooper's *The Disagreeable Oyster* (1956), Samuel Beckett's *All That Fall* (1957), Douglas Cleverdon's *Opium* (1957) and Donald McWhinnie's *Private Dreams and Public Nightmares* (1957).

The abovementioned works were all significant in exploiting how sound is used theatrically, the relationship between sound and words or the sound of words. *All That Fall*, a collaboration between Samuel Beckett, Donald McWhinnie and Desmond Briscoe, used sound and sound effects to capture alterations between dream and reality to the point that the two became indistinguishable. (Niebur 2010:19). In playing with different layers of sound these compositions appear to suggest different 'worlds' as well – in the above case, dream and reality. It is all related, it would seem, to eroding the idea of music occupying a discrete sphere, of music as something set aside from the everyday, of music as something that establishes an autonomous aesthetic domain. It is possible to connect this to an interest in the industrial world with its prevalence of 'noise', as well as to the Modernist interest in interiority. Such experiments are an assault on music itself to the extent that music is understood as a civilized and cultural activity that maintains a boundary with the world outside.

*The Disagreeable Oyster* reveals the schizophrenic journey of the lead character torn between his domestic life and the pursuits of his opposing personality. Whereas his domestic life consists of a wife and a job, his alter ego gets drunk, runs wild and has homosexual encounters. Here, references to femininity and at times his dialogue with his inner voice are represented through a distorted sound world. (Niebur 2010:25) *Opium,* originally based on an excerpt from Jean Cocteau's journal describing the effects of opium, used the manipulation of the sound of words to capture the feeling of drug-induced euphoria. (Niebur 2010: 28) Similarly, the manipulation of words was primary to the radio poem *Private Dreams and Public Nightmares*, with McWhinnie endeavouring to create a hybrid genre between radio drama and electronic and concrete music, allowing each element to have equal importance in its production. (Niebur 2010: 29) There was an attempt to capture inner worlds that are demarcated by a different sound world.

From these early beginnings, the Radiophonic Workshop eventually became fully established, to the point that in 1958, it was commissioned for 150 programmes, including the famous *Doctor Who* theme, which was produced by Delia Derbyshire at the studio. The studio continued its work until 1998. (Bogdanov 2001: 43) At the same time that The Radiophonic Workshop was in the process of establishing itself in the late 1950s, the Polish Radio Experimental Studio was established by Wlodzimierz Sokorski in 1957 (Pasiecznik 2011), and the Institute of Sonology at the University of Utrecht, Holland, was established as a successor to the Phillips Research Laboratory in 1960, and came under the directorship of Gottfried Michael Koenig.

In Japan, the potentialities of *Elektronische Musik* and *Musique Concrète* were embraced for their compositional virtues. The tradition of Japanese electronic music was pioneered by Toshiro Mayuzumi and Toru Takemitsu, who together established an experimental studio at the Radio Nippon Hoso Kyokai (NHK) in 1954. (Holmes 2008: 112) The technologically savvy Japan, under the commission of the Tokyo Telecommunications Engineering Corporation, now Sony, provided tape recorders and studio facilities to composers as early as 1951. The NHK studio is widely regarded as the primary force in establishing electronic music in Japan. (Holmes 2008: 114)

The central theme of electronic music and *Musique Concrète* was experimentation. The sound studio was conceived of as a laboratory that saw its purpose as the search for new sound mediated by the potential of new sound technologies such as magnetic tape and the electronic synthesis of sound. Among these experiments, there were instances where space became a focus of interest and as a result composer began thinking of space in new ways. This led to a new conception of the stage as well as a renewed interest in space as a compositional tool within the largely temporal art of music. The compositional techniques and the interest in space certainly had a direct impact on the development of sound art, which is discussed later. For the purposes of this section it was sufficient to make intermittent reference to the technological narrative of sound in relation to *Elektronische Musik* and *Musique Concrète.* The next chapter will deal specifically with the technology of sound recording and playback and its importance to sound art.

# CHAPTER 3: SOUND RECORDING, PLAYBACK AND SOUND ART

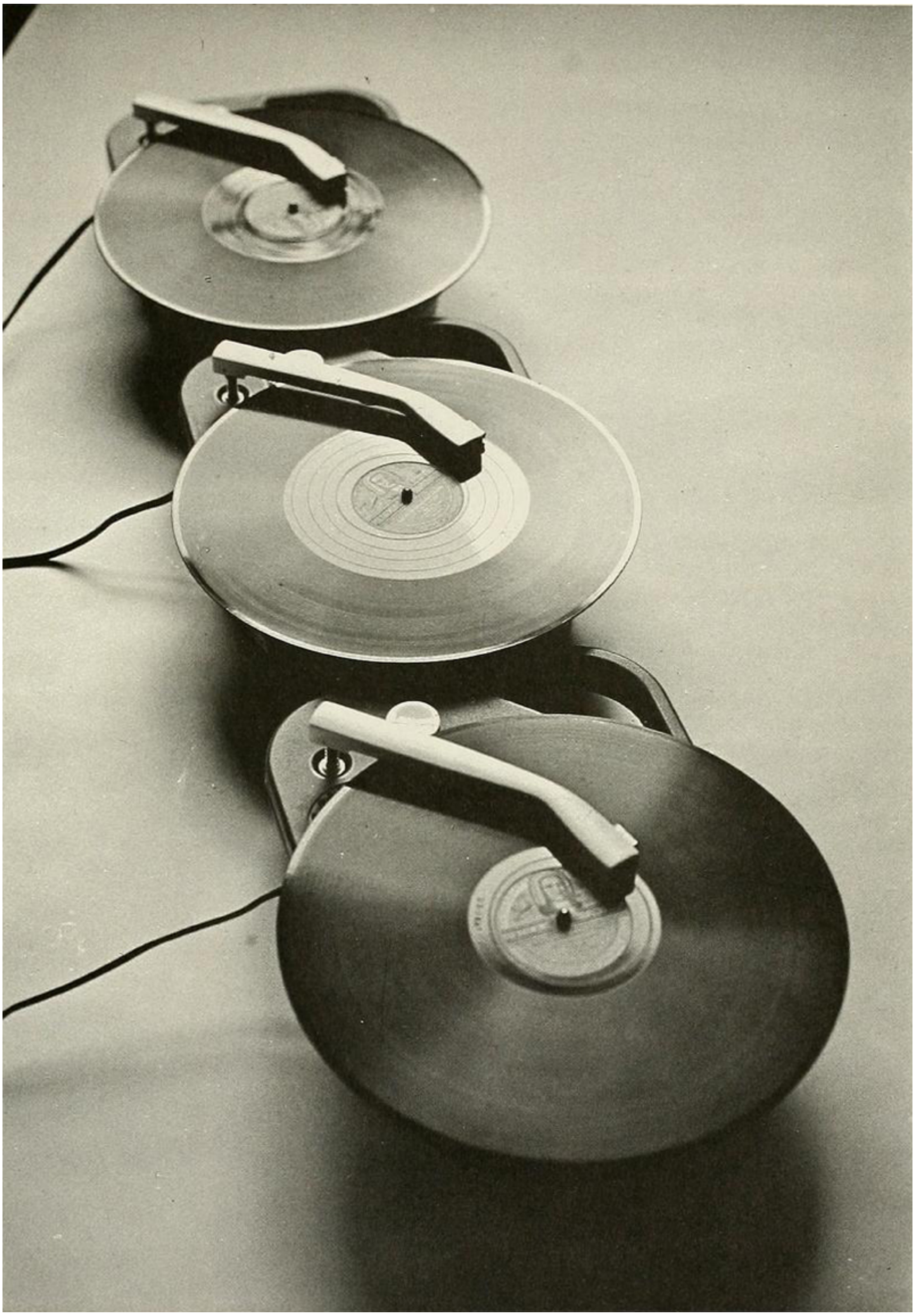


**FIGURE 3: Anastasi, W. *The World's Greatest Music* (1977)**

> Well, first of all, a loudspeaker is a musical instrument with a tone quality of its own – a very poor tone quality! What we're told is that it's even better than the original in some ways, that it lacks the drawbacks of acoustic instruments and the imperfections of human performance. This is the kind of thing I can't believe.
>
> (Brant & Oteri 2006:199)

> Originally all sounds were originals. They occurred at one time in one place only. Sounds were then indissolubly tied to the mechanisms that produced them. The human voice travelled only as far as one could shout. Every sound was uncounterfeitable, unique. Sounds bore resemblances to one another, such as phonemes which go to make up the repetition of a word, but not identical.
>
> (Schafer 1977: 90)

It is difficult to imagine how sound art would have come to be without recording and playback. One of the aims of this dissertation is to function as a primary resource for sound artists in Johannesburg and this would not be possible without retelling the story of recording and playback. Although this has been done many times over, here, I will write it from my own perspective.

The term "schizophonia" was originally coined by Schafer in 1969 to denote the split between "original" sounds and their electroacoustic reproduction. One of the implications is that of 'listening without seeing', the acousmatic experience which I have already mentioned. In this case, schizophonia and recording has the inherent ability to remove sounds from the sphere of automatised perception, which I will discuss in Chapter 5. Whether we are listening to the radio, watching a film or seeing a band play, much of our listening is mediated by reproduction. These sonic experiences are often highly constructed in ways that could, for example, create artificial temporal sequences and particular senses of space. In the next section I will discuss how sound recording and reproduction developed into what it is today and show how significant technological developments played a role in the emergence of sound art.

## Historical Background

Before sound recording and reproduction, oral transmission, social memory from community to community from generation to generation, was a primary means of keeping music alive until the arrival of sheet music. Sheet music, in the West, replaced many of these modes of transmission as a primary means of distributing music. Rail travel aided this as musicians and composers became able to more easily traverse the landscape to perform their works. Unless one lived in a major city, it was unlikely that one could attend these concerts, but the piano made music more accessible. Within this context, the piano, and music written specifically for piano, became an early precursor of the domestication of music. During the latter half of the 19th century the piano was widely regarded as a middle-class status symbol, an indicator of affluence, prestige and cultural accomplishment, (Johnston 2011: 165) The role of sheet music and transcription was important in this regard. Music publishers recognised that the piano was a social instrument and at the turn of the century two-player scores were introduced. Manufacturers knew that a level of musical competence was a prerequisite for playing scores and as a result they began to produce player pianos, which reproduced a given score 'recorded' onto a roll of perforated paper. While a pianist would play a given score, a series of holes corresponding to the notes played would be mechanically punched into a paper roll. The spool could then be fed into a player piano that would replay exactly what the pianist had played.

Another early precursor, which influenced the manner in which sound was to become recorded and reproduced, was the telegraph. Invented by the American Samuel Morse, after much trial and error, the idea was to transmit messages through a wire over great distances by means of electronic signals. Having succeeded in doing so and most likely aware of preceding code systems, Morse invented his code in 1838, using varied combinations of dots and dashes that represented numbers and the alphabet. It was in 1844 that the same code still used today came into being. On May 24, 1844, the first official message in Morse's code, "What hath God wrought!" from Numbers 23:23, was sent from the supreme court chamber in Washington, D.C. to the B&O Railroad Depot in Baltimore, Maryland. Interestingly, the message is said to have been credited to Miss Annie Ellsworth, daughter of the US commissioner of patents in whom Morse is said to have had a romantic interest. The message has been misinterpreted as having ended as a question mark when in fact it was an exclamation mark. (Coe 2003: 32)

Before Thomas Edison turned his attention to sound, Jean-Marie Constable Duhamel, for example, joined a pencil to a tuning fork. When the tuning fork rang, the pencil transcribed the sound waves onto a piece of paper. Thereafter, Thomas Young replicated Duhamel's experiment but instead of using a piece of paper, constructed a device that would etch the sounds onto a wax cylinder. Leon Scott used a similar transcription mechanism, which transferred sound waves by means of a stylus onto a cylinder coated in soot. (Morton 2004: 2) As much as the phonautograph was said to be the first physical recording of sound, importantly it was modelled on the human ear, in a shift that was characterised by theorising sound as "any phenomenon that excites the sensation of hearing". (Sterne 2003: 33)

An important development in the history of electronic sound reproduction is the invention of speakers. The fundamental operational concept of a speaker was first described by the German inventor and industrialist Ernst W. Siemens. Initially, Siemens did not use this device for audible transmission as did Bell in his 1877 telephone. Nevertheless, the flaring 'morning glory' trumpet-like shape later common to all phonographs was exclusively attributed to Siemens. (Schoenherr 2001: Loudspeaker History) Importantly, Bell was initially motivated by the idea of inventing a hearing aid for deaf people. He built an ear phonautograph, loosely based on Scott's phonautograph of 1874 and, not succeeding, focused his attention on telephony. (Sterne 2003: 39-40) In the same year, the first long-distance telephone line became operational, connecting French Corral and Bowman Lake over a distance of 97km.

## The Acoustic Period

To recall an earlier discussion, much was already known about sound, Helmholtz and Lord Rayleigh already having published their major works on the subject. Then, in 1877, Frenchman Charles Cros drew from earlier experiments and the existing science and invented the Parleophon. The fundamental workings of the Parleophon became one of the major sources of inspiration for Edison's phonograph; he was unable to afford the patent for his invention. At the time, Edison had been searching for more efficient and automated ways of improving telegraphy and in the process, Cros' invention inspired his interest and through trial and error he arrived at his own version. Edison's hand-cranked machine of 1877, which transcribed sound onto a cylinder covered in tin foil with a stylus, is said to mark the first occasion when sound was successfully recorded and played back. The basic process of the acoustic era of recording had begun and Bacon's artificial voices had become a reality. (Millard 2005: 17)

The early recordings were extremely poor, and it would take some time and many improved versions of the process before sound recording would transform from the novelty that it was in the early 1900s to the mass duplication medium of 1917. Moreover, because of the lack of quality sound recording and playback, the scope of what could be recorded was quite narrow. Nevertheless, by 1917 the three major players of the recording industry, Edison, Victor and Columbia, had been established. Significantly, the operation was run as an assembly line and there was an important distinction between the artist and the engineer, both of whom plied their trade in what was then called a laboratory, which soon became known as the recording room and the engineers known as the recordists. (Millard 258: 2005)

These early recording rooms were all essentially the same, rectangular in shape, the walls draped in thick curtains to prevent excessive reverberation and a small partition in the room separating the recordist and artist. The act of recording was also fairly makeshift, and recordists had to learn on the job. There were a variety of horn shapes that would channel sound in different ways to a membrane and a variety of membranes, thick and thin, made of different materials, which would translate the vibrations to the stylus. Part of the recordist's art was to give instructions to the performer: how close to or far from the horn they should stand and which adjustments they needed to make in their performance to achieve the best balance of sound in the final recording. Even though many of the early recording techniques were considered to be trade secrets, the essential components of sound recording would persist as the quality of the recording medium was improved and as recording became electrified. The most important factor was that sound recording happened in a controlled environment.

## The Electronic Period

The idea of converting acoustic waves into electric energy (by means of the microphone) as well as converting electrical energy back into acoustic energy (by means of the loudspeaker) was already well known to telephony but two major developments drew the interest of the recording industry. The first was sound amplification in the form of the vacuum tube, invented by Lee De Forest in 1906, and the second was the condenser microphone, invented by E.C. Wente in 1917. The electrification of recording gave the sound engineers greater control over the sound and better-quality recordings with less noise. Furthermore, greater attention was paid to the acoustics of the recording studio as a result of the sensitivity of the microphones. The recording space needed to be isolated from outside noise and the reverberation kept to a minimum. During the 1920s and 1930s many of the recording techniques cross-pollinated between radio, film and the recording studio, such as microphone placement and the use of multiple microphones. Before the advent of stereophonic sound, these rudimentary measures simulated space and it was common in the 1920s for recordings to be made with two microphones. Mixing dialogue, music and sound effects for film and the early RCA mixing console made this possible. Post-production sound editing techniques such as cutting and re-joining also emerged from film in the 1920s. Two key inventions made this possible. The first, made by Lee de Forest and Theodore Case, was Phonofilm, a technique for recording sound waves photographically onto film. The second was the Moviola, invented by Iwan Serrurier in 1924, which allowed film and sound to be edited simultaneously. (Millard 276: 2005) Now the editor could listen to the soundtrack while viewing the film. Even though this allowed for more flexibility, the sound and the image still had to be edited simultaneously and, realising that sound and image did not necessarily need to be recorded at the same time, film makers began using dubbing techniques, a process of making a recording of a recording.

During the same period, Western Electric Laboratories was also working on a vastly improved loudspeaker, and the development of the moving coil transducer in 1925 by C.W. Rice and E.W. Kellogg meant that the mechanisms for sound projection allowed for greater control and quality of the sound reproduction. Even though Bell had already experimented with a two-channel sound transmission system early on in the development of the telephone, it would only be as a result of the improved loudspeaker that multichannel recording and playback would become the focus of music and film. For this to happen, medical science and a more specialised understanding of binaural hearing and sound source localisation underwent significant influence from acoustic science (Théberge et al. 15: 2015), discussed in greater detail in Chapter 5. The original conception of stereo sound came from an English engineer, Alan Blumlein, who was working at EMI in 1931 for the purpose of recreating the *natural* experience of auditory space with two channels. Many early experiments were also conducted at Bell Labs under the direction of Harvey Fletcher. One of these involved replacing the ears of a mannequin, affectionately called Oscar, with microphones. The sound was then captured and transmitted to a set of headphones as a 'realistic' mimicry of auditory perspective. Oscar was exhibited at the Chicago 1933 Century of Progress Exhibition. Bell Labs also experimented with recording two distinct audio channels at the same time and did so successfully for the first time in 1932, in what was likely to have been the first stereo recording. (Kerins 2011: 21) In the following year, they transmitted an orchestral mix from Philadelphia to Washington, D.C., projecting it to the audience through a three-channel speaker system.

What emerged from the early experiments with multi-channel sound were three models for the reconstruction of auditory space that culminated in a demonstration by Bell Labs in 1937. These were the binaural model, which sought to recreate the experience of directionality of sound; the stereophonic, which sought to recreate the motion of sound; and the constructed model, which sought to combine the binaural and the stereophonic where both stationary and moving sounds created a spatial narrative. (Kerins 2011: 22) It is important to recognise that demonstrations of this sort were also a means of listener training. The average home listener with a stereo was being initiated into a framework of spatial listening tailored to suit their listening needs. Here, the idea of 'the best seat in the house' was reinforced by the ability to adjust playback variables such as speaker placement, volume control and equalisation.

This synthetic auditory space and the resultant multiplicity of auditory perspectives (Théberge et al. 2015: 20) once again owes much to the way it came to be moulded around the visual domain of cinema. Initially, the auditory space in cinema attempted to recreate the spatial organisation of the theatre. Dialogue came from speakers situated behind the screen and music from a separate set of speakers, replicating the orchestra situated in the pit beneath the stage. In these early monophonic arrangements, the task of switching between soundtracks and between projectors belonged to the projectionist. As the demand for an increase in the number of speakers as well as the number of soundtracks grew, so too did the switching systems, culminating in Vitasound, an automated sound switching system that switched sound according to sprocket holes in the filmstrip. Vitasound soon evolved into Fantasound, the first truly multi-channel sound system famously used in *Fantasia* (1940). Three independent channels projected three independent audio tracks and 96 smaller speakers were located behind and around the audience. (Kerins 2011: 22)

While the development of the crucial components of sound technology happened quite rapidly, the recording process was still cumbersome, highly technical and the domain of specialists. Recordings were etched onto a master disc, and a mould was then made of the master disc from which duplicates could be manufactured. What is more is that the recordings were confined to a fairly short time limit defined by the radius of the disc. Nevertheless, during the 1920s a fairly old format of recording, magnetic recording, would resurface out of the need for radio to broadcast pre-recorded content.

Invented by Valdemar Poulsen in 1898, the original patent included a recording head magnetising an electronic audio signal along a wire passing along it, in accordance with the intensity and polarity of the electronic signal. These patterns of magnetisation could then replay the sound. (Mathur et al. 2014: 81) Poulsen's attempts to popularise his invention resulted in him selling the patent to German investors in 1901. There was little commercial success, however. In the 1920s, when the patent expired, Curt Stille commissioned Vox Machinen A.G. to produce wire recorders of Poulsen's design. A version of the Vox recorder, the Blattnerphone, soon made its way to the BBC for use in shortwave broadcasting. Wire was soon replaced with magnetic tape, in a version of the recorder that was known as the Marconi-Stille recorder. At the same time, the German radio broadcaster, the RRG, showed interest in magnetic tape recording and as a result, the technology became vastly improved, which eventually resulted in the AEG Magnetophon in 1935. (Morton 2000: 54-59) The Magnetophon was far less bulky and more reliable than the earlier machines and because of the transition to magnetic tape, the recording quality improved, longer recordings were possible, and the tape reels became easier to transport. These improvements were then translated into the 1948 Ampex model 200 and the Brush BK-401. Apart from longer recording times and the portability of magnetic tape, the machines made recording a relatively inexpensive exercise and because tape recording was not influenced by vibration, the recording did not necessitate a controlled environment. This being said, the most significant influence that magnetic recording had was that magnetic tape, like Phonofilm, could be edited by cutting and re-joining tape.

Because early tape recorders did not yet make better recordings than the already established disk systems in use, it was not until 1947 that they became more widely used in commercial recording studios. (Millard 289: 2005) I have already mentioned some of the features that made tape appealing, such as longer recording times and the application of editing techniques from film. Of these techniques, dubbing was playing a significant role in making tape a worthwhile medium to record with, particularly for music. Given an Ampex tape recorder by friend Bing Crosby, Les Paul began to experiment with dubbing. His recording *How High the Moon* (1951), for example, has 12 overdubs in a guitar orchestra where one person plays 12 guitars simultaneously. Overdubbing so many times also gave the guitar a fuller sound and was a means of simulating a reverberant space. Recording onto tape, the flexibility it allowed, and the durability of the medium signalled a shift away from the commercial recording studio and, as reel-to-reel machines became smaller and less expensive, towards the home recording studio. Thus, in the context of sound recording and editing, tape inaugurated a move away from composition and orchestration being the domain of experts towards a more ubiquitous middle-class activity. Lastly, the tactile nature of editing tape also draws the listener's attention to the material quality of sound or the sound object, as is immediately evident in the work of Pierre Schafer and Pierre Henry, two composers mentioned earlier.

## The Digital Period

The digitisation of sound emerged during the 1920s through research efforts in the telecommunications industry, which were focused on pulse-code modulation or PCM. Here, a continuous sound is broken into sections and these sections can be given an approximate numerical value. The numerical values are then transmitted into electrical pulses that become sound again. (Millard 347: 2005) Notably, because the numerical values could be encrypted and decrypted, the technology was accelerated during World War II. The basic concept of PCM was then carried forward into the computer age where the varying measures of electrical currents that recorded and reproduced sound were translated into binary code. Complex numerical parameters could now be expressed as groups of 0s and 1s. Thereafter, it became a question of the speed at which the code could be processed as well as the most suitable means of storing the code. Both issues were resolved in the 1960s and 1970s during the rise of computer technology, with its need to process and store all kinds of information. The digitisation of sound also meant that the quality of the recording would no longer be subject to the medium that it was recorded onto or played back from. Sound could be recorded and played back with no loss in the quality of the sound sample because the code that represented the sample would not change.

Even though digital recording did not impact the basic format of the recording studio, the move towards digital sound meant that the recording process became more clinical and that more functionality was added to the production process. Not only were more channels added to mixing desks, which allowed for a more complex layering of sound, but the ability to process the sound was also supplemented by an array of filters and effects units. Importantly, the digitised sound, as defined by a set of mathematical parameters could be fabricated without the need to record any real sound at all. This captured the imagination of many engineers and composers such as Stockhausen.

The 1950s also saw the invention of music synthesis on a digital computer, when a Bell Telephone laboratory engineer, Max Mathews, in collaboration with John Pierce, hit upon the idea of synthesising musical sound using a computer in the process of researching new telephonic technologies. The IBM 704 filled a huge Madison Avenue showroom and was expensive to use, which limited its availability to universities and laboratories. (Wang 2007: 193-194) At a New Jersey summit in 1957, Mathews exhibited his “transducer”, based on the principle of converting audio signals into digital information that can be stored and manipulated by a computer and then reconverted into an audio signal. (Taruskin 2009: 495) Fundamentally the MUSIC-N programming language developed by Mathews was mainframe specific and MUSIC-I, the first generation of the programme, was written specifically for the IBM 704. MUSIC-I was a monophonic program, which operated with triangular waveforms, instructed by the input of a ‘score’ file. Thereafter, there was a gradual improvement with MUSIC-II (1958) and a notable improvement in the functionality of MUSIC-III (1959) that consisted of a score and orchestra file, similar to earlier versions but enabling users to manipulate the sounds using oscillators and envelope generators, for example. (Doornbusch 2009: 45-49)

Throughout the development of computer music, the interrelationship between engineers, programmers, professional composers and the institutions that supported the research, needs to be emphasised. From its genesis, Mathews and others believed in the potential of computer music to overcome the limitations of creative sovereignty in relation to music. The enthusiasm for this prospect is evident in the liner notes Mathews wrote in collaboration with Ben Deutschman for *Music from Mathematics* (1962), a composition played by an IBM 7090:

> Man's music has always been acoustically limited by the instruments on which he plays. These are mechanisms which have physical restrictions. We have made sound and music directly from numbers, surmounting conventional limitations of instruments. Thus, the musical universe is now circumscribed only by man's perception and creativity.
>
> (Mathews, quoted in Taruskin 2009: 495)

Unfortunately, this enthusiasm often tapered off due to the laboriousness of the entire process – but Mathews persisted, and composers attracted by the potential of absolute control maintained their interest. During the developmental stages, Mathews and Pierce met with Milton Babbitt, Vladimir Ussachevsky and Otto Leuning and later Edgard Varèse but the most influential and first Bell Labs composer was James Tenney. Tenney initially joined Bell Labs in 1961 with the intention to work on psychoacoustics but soon found himself entranced by computer music, composing *Analog #1: Noise Study* (1961), made using MUSIC III, and *Four Stochastic Studies* (1962). (Doornbusch 2009: 48-49) By the late 1960s, analogue synthesisers and the Moog in particular had become widely available and Mathews and others developed computer control devices for sequencing and altering sound, which became a common accompaniment to the synthesiser. Where early computer music was the domain of laboratories and universities, the stage was set for a more widespread and independent exploitation of its possibilities, spurred on by the Apple II desktop microprocessor which became available in the late 1970s, and the first fully digital synthesizer (the Yamaha DX-7). Finally, a system that allows the components to connect to and communicate with each other called MIDI (Musical Instrument Digital Interface), also became available in the late 1970s. (Jones 2003: 88-89)

During the 1980s a lineage that dates to 1965 reached its peak with the widespread popularisation of the compact cassette tape. This was partly because its inventors, Philips Electronics, deliberately charged no royalties on the patent, essentially creating a democratic medium, reproducible by other companies, and also because the sound quality was greatly improved by Dolby noise reduction. The most significant factor, however, was its compact size and when The Sony Corporation invented the Walkman, also its portability. Furthermore, compact cassette tapes were not only a playback medium but also a recording medium, and thus met a consumer demand that took the compact disc, already invented in 1977, some time to meet. (Cole et al. 2003 29-30) Nevertheless, later improvements in laser technology and the appeal of digital audio quality that far surpassed that of analogue meant that cassette tapes soon became a redundant medium.

> Listening to a recording (even one that you have made yourself) of pre-recorded music amounts to nothing more than a collection of cultural products that exists with or without your "participation". The potential of the microphone/tape recorder is boundless – compact, battery operated, inexpensive and readily available – as an instrument for artistic and social expression. Any social or private activity that emits sound can be recorded.
>
> (Lander, 1989: Sound by Artists)

That Lander draws our attention to the technology of the time is historically significant. He suggests that it can be used for artistic purposes in the re-articulation and elucidation of social or private activities. This is not only a statement based on the availability of appropriated technologies but one that almost suggests that anyone can be a sound artist. Lander also speaks of playback and distribution: a sound artwork can be portable, be played in different spaces at the same time or at different times and it can be almost indefinitely reproduced. It seems to me that his excitement for the potential of technology in relation to the medium of sound prevented him from acknowledging the discreteness, the ephemerality and the inimitability that are important characteristics of many sound works.

The 1990s exemplified a major technological innovation that provided ideal conditions for the global emergence of sound art. Many centuries of globalisation, in particular cultural globalisation, were accelerated to an explosive degree by the Internet. The Internet established a network of exchange that was worldwide, instantaneous and for the most part easily and openly accessible. (Hopper 2007: 30) As a result, there was an upsurge in illegal copying and distribution of music, as was the case with Napster, a song-sharing host which became subject to a law suit by the Record Industry of America in 1999, culminating in its demise. Conversely, many artists saw Napster and similar file sharing sites as a way to circumvent the record industry and take greater ownership of their art and become more independent. (Lambert et al. 2005: 96) The Internet as a form of low-cost distribution, combined with technological advancements in sound and computing, culminating in the home studio, allowed an unprecedented degree of accessibility and exchange for artists working with sound.

As a gesture towards the potential of this interconnected virtual community, Atau Tanaka's *Global String*, developed in collaboration with Kasper Toeplitz in 1998, consists of a metal cable stretched diagonally across a room and connected to vibration sensors that convert its vibrations into a digital sound signal that is then transmitted onto the Internet. Essentially a monochord, the work not only makes physical the virtual but also turns imagined space into a site of performance, of dispersed geographies and synchronous temporality. (LaBelle 2006: 271)

In this section, I offered a brief overview of sound recording and playback in relation to some of the most pivotal technological developments that influenced the conception of sound. Three stages were identified: the mechanical, the electrical and the digital. Many inventions resulted from the cross-pollination between radio, telephony, film and sound recording. A number of key themes emerged in this overview. Beginning with the piano, music was becoming a middle-class domain, leading to the domestication of the concert hall with the improvement of microphones, amplifiers and speakers, all of which would take its final form as the home stereo. The introduction of stereophonic sound introduced home listeners to new ways of listening, structured by the synthetic spatial experience of sound. Beginning with volume control, more features were added to the home stereo and the listening practice became more individualised. The location of recording moved from laboratory to studio to home studio. Editing techniques drawn from film were applied to sound and became more widely available in the form of magnetic tape. Digital technology and the home computer had far reaching effects. Most notably, it accelerated the move towards the domestication of the studio and established mathematical models for the synthesis of sound.

## The Emergence of Sound Art

> From here [the 1960s], art self-consciously becomes self-critical of its own structure, offering critique to its institutions, from the museum to the language of art history, and relying more and more on a move away from the fabrication of objects to the dematerialized potential of events, actions, ideas, ephemera and the politics inherent to space.
>
> (LaBelle 2006: XI-XII)

The last quarter of the 20th century is elegantly described by Cox in his essay "From Music to Sound: Being as Time in the Sonic Arts" (2006). Cox proposes that, beginning with John Cage, the post-theological philosophical shift exemplified by Friedrich Nietzsche's "becoming" as opposed to "being", Henri Bergson's "duration" as opposed to "time", and Gilles Deleuze's concept of "the virtual", have all gradually converged, resulting in an era where "sound" has displaced "music". (Cox 2006: 80-81) For Nietzsche, "being" is a fabrication, coexistent with the concept of God and, briefly speaking, he proposed that "the 'doer' is merely a fiction added to the deed – the deed is everything". Hence the fluidity of becoming for Nietzsche replaces the fixity of being. Bergson questions the quantification of time, suggesting that the spatial compartments between past, present and future conceal their fluidity, the aspect of events bleeding into each other. What Bergson calls "duration" is therefore the medium that produces beings and events, in a continual durational-plain of transformation. Deleuze, for his part, expands Bergson's theory of "being as duration" and separates "the real" into the coexisting "actual" and "virtual". The actual draws on the virtual through memory, actualising the potential of the virtual, and the virtual is represented by the continuous fluid becoming of the past into the present. (Cox 2006: 80-81)

That sound displaced music is not to say that music ceased to exist but that the focus on sound was an attempt to connect music to contemporary notions of duration and becoming. According to Thomas Mann music, unlike the plastic arts, articulates time, foregrounding the experience of duration while audibly narrating, in a structured way, our sense of continuity. (Mann 1947: 541) The listener is stationary, and the music accentuates change. The plastic arts cannot do this. Here, static objects are wholly located in the present and are perceived to be permanent and the experience of time as change is articulated through the viewer's relation to the object. Time is thus translated into spatial relationships between objects where no two objects can occupy the same space at the same time; they are perceived sequentially as one object next to another or one viewpoint that replaces another viewpoint. The emergence of sound art, when seen in relation to other time-based art forms such as performance art and experimental music, and spatial practices such as installation art and site-specific art, could then potentially be seen as occupying the middle ground between the narrative time of music and the spatial time of the plastic arts. Sound art foregrounds both the temporal and the spatial. Like music, the sound continuously unfolds as a sequence of 'viewpoints', connected by the perception of continuity. The sound is also modulated by the acoustics of the space and the listener's changing proximity to the sound, where one listening point replaces another. Thus, as a consequence of this continuous unfolding and becoming, the listener's spatial relationship to the sound separates sound from music and art forms by the way that it audibly intensifies the sense of the present.

**FIGURE 4: Reich, S. *Pendulum Music.* (1968)**

With reference to John Cage's percussion music of the 1930s, lifelong collaborative projects with dance, pieces for prepared piano of the 1940s and his aleatory music and chance operations, Cox sees Cage's *4'33* (1952) in the context of "becoming", "duration" and "the virtual" as the first manifestation of the shift from music to sound. (Cox 2011: 82) For Cage, the Western tradition of music was essentially involved in the creation of "time-objects" that for the most part have a beginning, middle and end and thus attempt to divorce themselves from the fluidity of duration and becoming. (Cox 2011: 82) *4'33* On the one hand it refers explicitly to a duration of time yet simultaneously deems its measure arbitrary by using it to frame incidental and contingent sound which, Cox suggests, opens an aural window onto "duration" and "the virtual". (Cox 2011: 82-83) However, the aural window in Cage's work does not make time itself audible in the way that works like Steve Reich's *Pendulum Music* (1968) or Györky Ligeti's *Poème Symphonique for 100 Metronomes* (1962) do by making reference to rhythm, but opens an aural window onto the absence of sound, the presence of silence, the now of the sounds of the audience coughing or shuffling their feet on the floor. In *Pendulum Music,* the performers swing a microphone, suspended over a speaker and as the microphone passes over the speaker placed on the floor, the ringing sound of feedback is caused. The rhythm is determined by the amount of time that the microphone is not directly over the speaker. This gradually decreases as the swinging microphone loses its momentum. Similarly, in *Poème Symphonique for 100 Metronomes* a mechanical arm sets a hundred metronomes that are set at different tempos into motion. Over the course of the piece, the metronomes gradually lose their momentum and eventually they all stop. Whereas Reich and Ligeti draw attention to the element of chance by referring to rhythm and timekeeping in music, Cage refers to the element of chance by drawing attention to the duration of sounds.

The "acoustical and sensorial properties" (LaBelle 2009: 3) of sonic material and "duration", the time of sound matter itself as opposed to the time of music and meaning (Cox 2011: 84), are not mutually exclusive, even though the discourse of sound art has tended to foreground the former. The Cagean legacy was significant for particular artists working in the 1960s such as Max Neuhaus, La Monte Young, Alvin Lucier, Robert Morris, Michael Asher and Bruce Nauman, who were all beginning to experiment with sound.

Between 1966 and 1976, Neuhaus took groups of people on sound walks from the corner of Avenue D and 14th Street in Lower Manhattan to the East River and back to his apartment on the Lower East Side in a work called *LISTEN,* his first independent work as an artist. The *in situ* work not only extended the Cagean notion of indeterminacy in terms of the unpredictability of the sound scene for each walk and its metamorphosis over a decade, but also enacts a kind of reconnaissance listening which unfolds as a consequence of moving through and navigating the urban soundscape. Thereafter, as if in response to the aura of the urban soundscape that Neuhaus must have grown intimately close to, he installed a permanent addition to sidewalk sounds in *Times Square* (1977-1992 & 2002-present). At the intersection of Broadway and Seventh Avenue, between 45$^{th}$ and 46$^{th}$ Streets, Neuhaus installed sound circuitry into a subway ventilation grate. The subtle textures of sounds, mostly traffic noises, metallic drones and other everyday noises, shifting into morning, noon and night, lightly reverberate through the subway shaft and permeate onto the street. (Fitzpatrick 2009: 228) The listenership of *Times Square* is fleeting and perhaps at times wholly unaware of itself. Passing over the vent might arouse suspicion in the listener of a concealed domain, the underground. This is listening where the blending sounds, real and reproduced, stimulate a continual re-evaluation of the site and a momentary glimpse of the "flow of duration". (Cox 2011: 85)

Re-evaluating the role of the composer was an important question after Cage. On the one hand, music organises and arranges sound, imposing an order onto sounds, and on the other hand sounds themselves are random and disorganised. This leads to an impasse, which Cage explains:

> Again, there is a parting of ways. One has a choice. If he does not wish to give up his attempts to control sound, he may complicate his musical technique towards an approximation of the new possibilities and awareness. (I use the word "approximation" because a measuring mind can never finally measure nature.) Or, as before, one may give up the desire to control sound, clear his mind of music, and set about discovering means to let sounds be themselves rather than vehicles for man-made theories or expressions of human sentiments.
> (Cage 1958: 3)

Cage's aleatory music attempts to resolve the tension between organising sounds and allowing them to be themselves by providing the conditions for sounds to happen randomly. A student of Cage, La Monte Young, extended this notion. La Monte Young began his early career as a composer who frequently blurred the lines between composition and improvisation. His early works, between 1955 and 1958, which were founded on serial principles evident in compositions such as *Trio for Strings* (1957), were centred on an exploration of long, sustained notes. Shortly after, under the influence of Cage and between 1959 and 1961, Young began to explore an expanded vocabulary of performance, which was strongly connected to Cage's theoretical pursuit of sound as unrestrained, liberated and removed from the determinant composer. Young sought to dismantle the external layers of sound in search of its essential internal core, pure sound, the beginning of which is evident in one of his early Fluxus works, *Composition 1960 #2* (1960). (Potter 2000: 22)

> Build a fire in front of an audience. Preferably, use wood although other combustibles may be used as necessary for starting the fire or controlling the kind of smoke. The fire may be of any size, but it should not be the kind which is associated with other objects, such as a candle or cigarette lighter. The lights may be turned out. After the fire is burning, the builder(s) may sit by and watch it for the duration of the composition; however, he (they) should not sit between the fire and the audience in order that its members will be able to see and enjoy the fire. The composition may be of any duration. In the event that the performance is broadcast, the microphone may be brought up close to the fire.
>
> (Young, quoted in LaBelle 2006: 70)

One can imagine the nature of the sound emanating from a fire: uncontrollable crackling, whooshing and rumbling flames, a crescendo and decrescendo, completely unpredictable. Given the title *Composition 1960 #2*, the act of making the fire is presented as deliberate, as if strumming a chord. Although Young's compositions were greatly influential in the experimental art performances of the Fluxus movement, in 1962, in collaboration with Tony Conrad, John Cale, Marian Zazeela and Angus MacLise, he reintroduced elements of his early career, particularly the sustained tone (drone) in *Theatre of Eternal Music* (1962-1965). As the name suggests, not only did the group relentlessly endeavour to play as often as possible and perform for as long as possible, the primary focus of their tenacious performances was the sustained note, meditative and hypnotic. In an exploration of harmonics, the performances attempted to activate unique aural sensations and dreamscapes through exploiting the perceptual properties of the ear and its neurophysiological functions. (LaBelle 2006: 72) Theatre *of Eternal Music* and *Dream House* (1964) were designed for an audience that is not stationary and along with the unremitting duration, the activation of interweaving harmonies occur as the listener moves through the space. The two works represent the fruition of Young's oeuvre and are of great significance to the development of sound art, especially for the interrelationship of time and space and the crossover between musical sound and non-musical sound.

Whereas Young's work attempts to reduce sounds to long sustained harmonies as activated by the motion of the listener, Alvin Lucier's work investigates the potential of discrete sounds produced by an almost stationary performer. In *Music for Solo Performer* (1965) silver electrodes are attached to the scalp of the performer and activated by alpha brain frequencies at 10hz produced by the brain when the eyes are closed. The piece draws inspiration from Hans Berger's 1929 discovery of alpha brain frequencies that typically appear during wakefulness when the subject's eyes are closed and disappear when they are opened. (Baars & Gage 2010: 269) Speakers placed throughout the performance area reproduce percussion instruments at modest amplitude. The alpha brain frequencies (in the range 8-12Hz) are made audible as sound waves and are produced during the intervals that the performer closes his/her eyes. (Austin & Kahn 2011: 79-80) Here, Lucier expresses the potential of a bionic performer, extending the performer's neurological circuitry into a series of wire tentacles that hum and hiss – rhythmically oscillating between visual and auditory space.

In perhaps Lucier's most widely known work, *I am Sitting in a Room* (1969), the composer sits in a room and repeatedly recites the passage below. As the passage is recited, the words are continually recorded and replayed in the room. The more the words are recited, the more the density of layers increases, to the point that the sound becomes an unrecognisable mass:

> I am sitting in a room, different from the one you are in now. I am recording the sound of my speaking voice and am going to play it back into the room again until the resonant frequencies of the room reinforce themselves so that any semblance of my speech with perhaps the exception of rhythm, is destroyed. What you will hear, then, are the natural resonant frequencies of the room articulated by speech. I regard this activity not so much as a demonstration of a

> physical fact, but more as a way to smooth out any irregularities my speech might have.
>
> (Lucier, quoted in Senft 2010: 67)

Morton's writing on the work is telling. He proposed that "retroactively, the room was already present in the voice". (Morton 2007: 48) In this sense the piece gradually unfolds as a rather violent illustration of the physics inherent to the voice in a space that resembles Rachel Whiteread's *House* (1993), where the interior is filled with cement. Lucier is deliberately unspecific about the room, only insisting that it is not the room that you are in. Thus, the details of the room are articulated through the resonance of the voice; in the imagination of the listener, the more the voice layers itself, the more detailed the expression of the room becomes. This is an attempt to obliterate the distinctions between sound and space; the space becomes the sound, and vice versa.

While *I am Sitting in a Room* is an acoustic articulation of an environment that throughout the duration of the work becomes more descriptive. Robert Morris' *Box with the Sound of its Own Making* (1961) attempts to entrap the sound of the gradual creation of a space. The walnut cube (24.8 cm X 24.8 cm X 24.8 cm) contains a 3.5 hour-long tape loop, consisting of the sound that was produced while making the box. *Box with the Sound of its Own Making* gives prominence to the instruments of carpentry and the workshop as well as compressing and confining them into a ready-to-ship commodity. It is not only the site of its creation, the workshop, that is important but also the containment and portability of site and soundscape.

By extending the concept of *Box with the Sound of its Own Making,* Los Angeles based installation artist and minimalist Michael Asher's work created "silenced" white rooms. In a group exhibition entitled *Spaces* (1969) Asher formally references geometric abstraction, building walls within a room that are placed askew yet merge with the room's proportions so that the viewer would ordinarily not notice the alterations: the room itself is the object being displayed. Importantly, Asher's room is installed with sound absorbing and deadening material. Thus, the white room places the viewer in an immersive visual and aural vacuum that heightens the potential energy inherent to a blank field of sensory deprivation; Asher puts the listener in the box (Ratcliff 2000: 88 – 89)

Similarly, Bruce Nauman's architectural manipulation in *Acoustic Wall* (1968) consisted of a wall that cut diagonally across the room, operating on a similar premise to Asher's rooms. However, it was designed to be more of an interactive than immersive environment.

This wall, too, was treated with sound absorbing material and was also white but terminated at a dead end so that the further the viewer travelled along the wall the quieter it would become, finally reaching the point of infinite silence or at least the suggestion thereof. The listener's proximity to the *Acoustic Wall* emphasises something "claustrophobic" (Nauman 2005: 134): the nearer the listener the more the ambient sounds are silenced. It becomes a space of auditory solitude: when the listener moves away, the ambient sounds return as the auditory space becomes gradually more saturated by the sounds of social activity.

In this section the early precursors to sound art based on the chronology of LaBelle and Cox were discussed. It became evident that art began to become especially critical of its own institutions – the museum, the gallery and the art market – by turning to new art forms and mediums. In this context, sound came under new scrutiny because of its relationship to other art forms such as music, performance, installation and site-specific art, but it also became used exclusively as a medium by artists. A number of influential examples, that are discussed in the next section, would lead to the emergence of the term sound art and various attempts to define it.

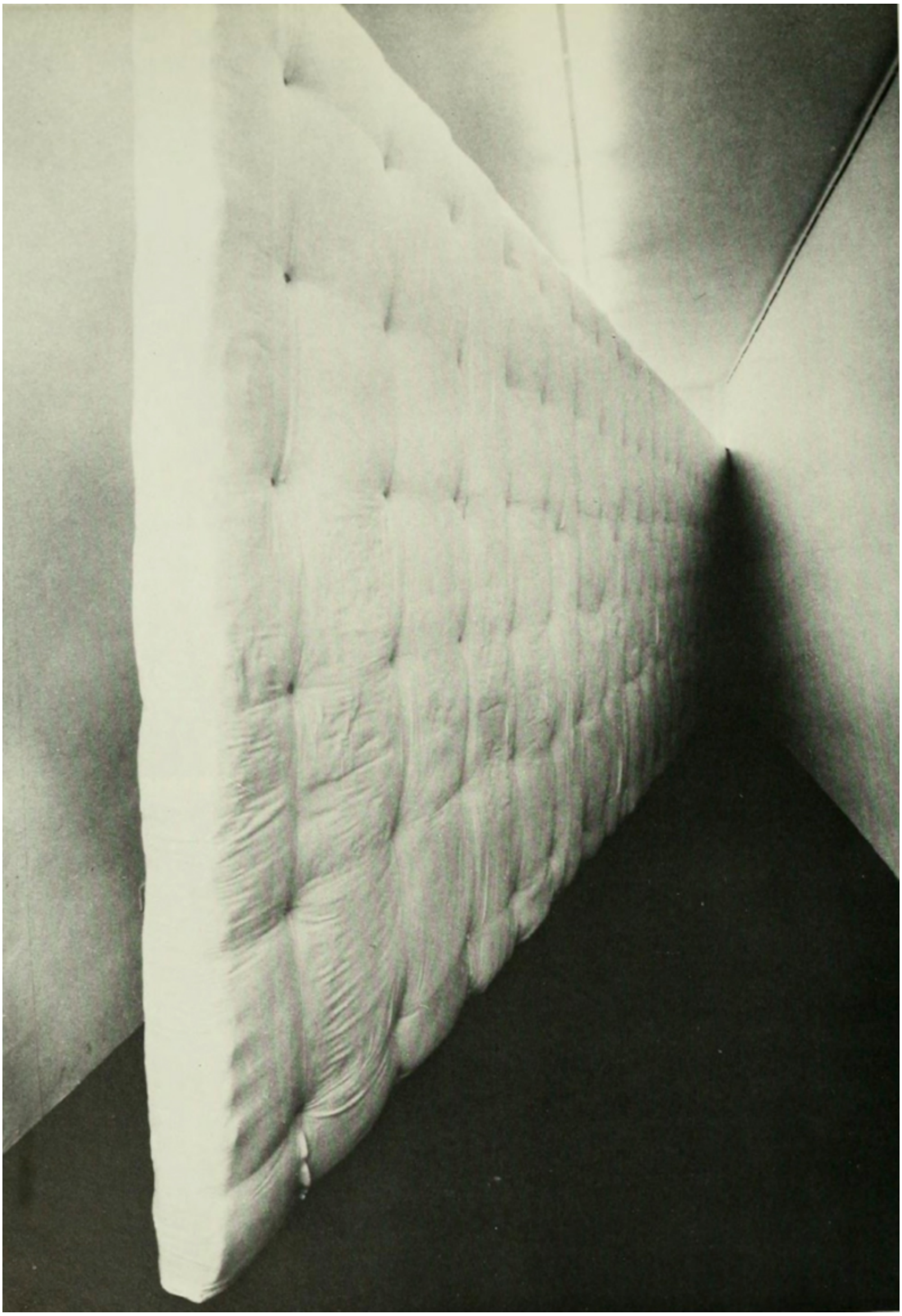


**FIGURE 5: Nauman, B.** ***Acoustic Wall*** **(1968)**

## Defining Sound Art

The overlapping and convergence of sonic and spatial practices in the latter half of the 20th century resulted in the proliferation of art that included sound, as well as art that made exclusive use of sound. In the last quarter of the 20th century sound became increasingly accepted into the canon of art. Within this context, there are three factors that contributed to the emergence of sound art. The first is a number of group and retrospective exhibitions during the late 1970s and the 1980s and 1990s. The second is the rise of sound art discourse that resulted in a number of important publications in the late 1990s and early 2000s. The third, enmeshed with the first and the second, is the search for a definition of sound art. Contemporary literature has referred to the way in which these factors coalesce and permeate into the present as "the sonic turn". (Drobnick 2004: 10) This period in the history of sound art is characterised by the rise of the Internet in relation to the decline of the record industry, the sharing of sound over the Internet and thus the historical moment when sound art started manifesting itself on a global scale.

The origins of the term sound art are debated. Numerous exhibitions in the 1970s and early 1980s and perhaps earlier, although not explicitly referring to "sound art", certainly contributed to the emergence of the term. In 1970, San Francisco-based artist Tom Marioni curated an exhibition entitled *Sound Sculpture As* at the Museum of Contemporary Art, which consisted of 9 sound sculptures/performances such as Paul Kos' *Sound of Melting Ice,* to be broadcast on radio simultaneously with Marioni's own work, which consisted of him producing a "descending sequence of tones" by urinating in a bathtub. (Ouzounian 2008: 4) Other artists featured at the exhibition include Mit Arbeiten von Arlo Acton, Terry Fox, Mel Henderson, Peter Macan, Jim Melchert, Jim McCready and Herb Yarno. In an attempt to retrospectively organise an exhibition as a summarising event of the 1970s, Susan Foley curated *Space/Time/Sound: Conceptual Art in the San Francisco Bay Area* (1979-1980), which included 21 artists or groups that throughout the decade worked with site-specific sculpture, installation art and events. Sound works were notoriously difficult to include given that many of them did not exist anymore.

At the same time, in a similar retrospective gesture, not under the guise of conceptual art but exclusively dedicated to sound, Los Angeles-based curators Robert Smith and Bob Wilhite organised *Sound: An Exhibition of Sound Sculpture, Instrument Building, and Acoustically Tuned Spaces* (1979), showing first at the Los Angeles Institute of Contemporary Art and then at Project Studios 1 in New York later that year, and including a recorded catalogue. (Appendix: Item 2)

In the same year, The Kitchen, famed for being one of New York's centres of experimentation and meticulous in the documentation thereof, hosted a conference and festival entitled *New Music/New York* (1979) featuring performances by artists such as Laurie Anderson, Robert Ashley, Don Cherry, Tony Conrad, Petr Kotik, Alvin Lucier, Charlemagne Palestine and the Steve Reich Ensemble, amongst others. The festival was renamed *New Music America* in 1980 and moved to a new city every year. Although works recorded during the first festival were never published, their rediscovery in 2004 enabled the compilation of remastered recordings published in collaboration between The Looking Glass Studio and Orange Mountain Music. (Appendix: Item 3)

In a similar effort to provide a retrospective overview as well as an accompanying recording, the Akademie der Künste, Berlin, organised an exhibition curated by René Block entitled *Für Augen und Ohren* (For Eyes and Ears) in 1980, consisting of seven large exhibition halls housing mechanical and electronic music making devices from the previous four centuries. The exhibition featured works by Laurie Anderson, Dick Higgins, Allan Kaprow, Bernard Leitner, Oskar Sala, John Cage, Harry Partch, Luigi Russolo, Joe Jones, Milan Knizak, Stephan von Huene, David Tudor and Harry Bertoia. Documentation of the exhibition was less about cataloguing the work using a track list. Instead, it was recorded by Charles Amirkhanian while walking through the exhibition, giving the listener a stronger sense of the experience of the sound in space. (Ode to Gravity, no date)

Another major retrospective exhibition and publication was held at the Neuberger Museum in New York in 1982, titled *Soundings*. Work on the *Soundings* exhibition began three years before the exhibition from a collective recognition of the importance of "sound in the plastic arts". (Delehanty 1981: 3) The works in the exhibition were grouped in various ways. There was a section of early work from between 1910 and 1940 that implied but did not make sound and another section of similar sound in work from the fifties and sixties. There was a section of sound sculpture that invited audience participation, installation work from the sixties, and various works by Joe Moss, Douglas Hollis and Liz Phillips that were located outside of the gallery. There also was a listening room with recordings dating back to the 1920s and a section that featured mechanical musical instruments that charted the technological developments in relation to sound. (Delehanty 1981: 3)

Given the spirit of the times and these curatorial initiatives, sound art gained unprecedented institutional support and gallery acceptance and shared the stage at festivals with musicians and composers, some of whom gained a measure of notoriety in the art world. This was followed by a further consolidation. In 1982 William Hellerman gathered like-minded artists and composers together to form The SoundArt Foundation and subsequently organised an exhibition entitled *Sound/Art* (1984), commonly cited as the origin of the term. (Licht 2009: 1) The exhibition, held in New York at The Sculpture Centre, included works by Vito Accioni, Connie Beckley, Bill and Mary Buchen, Nicholas Collins, Sari Diens and Pauline Oliveros, Richard Dunlap, Terry Fox, William Hellerman, Jim Hobart, Richard Lerman, Les Levine, Joe Lewis, Tom Marioni, Jim Pomroy, Alam Scarritt, Caolee Schneeman, Bonnie Sherk, Keith Sonnier, Norman Tuck, Hanna Wilke and Yom Gagatzi. It is worth noting that there are two important features of the title of the exhibition itself. The first is the way in which the title is used in ordinary conversation, when the forward slash is silent, and one could imagine someone asking: "Did you go to the sound art exhibition?" The second is the question inherent to the forward slash. Is it sound or is it art? This is important in how it recognised the uncertainty about the term, which would become one of the defining features of sound art.

The momentum of these early sound exhibitions was carried into the 1990s and 2000s, when the shows achieved a much larger scale. The term 'sound art' had now become widely accepted and institutional support grew, culminating in group exhibitions, retrospective exhibitions and festivals. The most significant of these was *Sonambiente* (1996), a survey exhibition of what was now readily referred to as contemporary sound art. The festival was a celebration of the Academy of Arts' tricentenialle, took place across 20 venues in Berlin featuring the work of 100 artists and was attended by approximately 50,000 visitors. Thereafter, three major exhibitions took place in 2000: *Sonic Boom: The Art of Sound* in London; *Volume: A Bed of Sound* in New York; and *I am Sitting in a Room: Sound Works by American Artists 1950-2000,* also in New York. This was followed by a series of similar exhibitions in the years that followed such as *Sonic Process: A New Geography of Sound* (2001) in Barcelona and the 10-year anniversary of *Sonambiente* (2006), also held in Berlin.

As these exhibitions and festivals contributed to the rise of sound art, they also stimulated debate over what sound art is. The literature around sound art has always been a crucial form of documentation because of the ephemeral nature of sound. Even though sound art defined itself through the relationship between artistic practice and discourse, it has generally evaded attempts to bring it under discursive control. In what follows I will situate some of the influential attempts to define sound art within our already established historical framework. In so doing, it is important to remain cognoscent of the fact that sound art has always been deliberate in its open-endedness, overlaps with other art forms and has been assimilative in the discourse devoted to defining itself. It can perhaps be said that the early discourse on sound art begins with the exhibition catalogue of *Soundings* in 1982. However, the first time that sound art was named and identified was in the exhibition catalogue for *Sound/Art* in 1984. In the introduction the historian Donald Letcher Goddard elucidates as follows:

> It may be that sound art adheres to curator Hellerman's perception that 'hearing is another form of seeing,' that sound has meaning only when its connection with an image is understood... The conjunction of sound and image insists on the engagement of the viewer, forcing participation in real space and concrete, responsive thought rather than illusionary space and thought.
>
> (Goddard 1983)

This early fragment foregrounds the experiential implications of sound art and how it works to reinforce the interaction with the visual. Goddard also makes a spatial distinction that contrasts the spatial illusion of perspective with the real space of environmental tableaus as activated by sound. The exhibition was premised on sound being read within the conventions of the gallery and this is most likely why Goddard draws our attention to sound's relationship to the visual. That presentation in a gallery was the prerequisite condition for sound to be art was soon overshadowed by the technological developments of the 1980s, as artists became increasingly interested in replicating the distribution methodologies of music such as the tape and the compact disc. Early examples are the PhonoStatic tapes, which became available in 1984 and the Tape-Beatles series in 1988. These technological developments prompted the next influential attempt to define sound art: a publication titled *Sound by Artists* (1990), an anthology of writing by both artists and musicians. This is perhaps the most significant milestone in sound art theory. In the introduction Lander states:

> Although there has been an abundance of activity centred around explorations into sonic expression, there is no sound art movement, as such. In relation to artists' works, sound occupies a multitude of functions and its employment is often coupled with other media, both static and time-based. As a result, it is not possible to articulate a distinct grouping of sound artists in the way one is able to identify other art practices.
>
> (Lander 1990: 10)

Four points are immediately evident in Lander's statement. The first is that he draws our attention to how sound is pervasive and overflowing; there is a sense of permeability and dissolution. The second relates to how he describes sound as occupying a multitude of functions and draws our attention to sound as polymorphous. Third, the indistinct grouping of sound artist suggests that Lander noticed that sound art is deliberately not situated. Lastly, Lander's bias is towards sound and he neglects Goddard's question of the visual. The aural versus visual debate only resurfaced in a notable way in the exhibition catalogue for the *Sonambiente* festival in 1996, Helga de la Motte-Haber asserts:

> *Klangkunst* in the narrow sense is, however, mainly defined through new aesthetical implications, which have crystalized over the course of a long historical process. To this belongs an abandonment of the strong differentiation between spatial and time-based qualities, which had already been questioned by the musicalisation of painting and abolished with the onset of process art. Through this, every purist concept of the artistic material, which assumed the division between the eye and the ear was dissolved. An art form emerged that wanted to be heard and seen at the same time.
>
> (Motte-Haber, quoted in Engström & Sjterna 2009: 12)

Motte-Haber is making a distinction between two separate historical processes that culminate in a point where the differences between them have become indistinguishable. Whereas *Klangkunst* refers exclusively to "a category of installation art, [which] involves working with spaces both acoustically and sculpturally" (Metzger, quoted in Engström & Sjterna 2009: 13), sound art is characterised by its openness and more closely adherent to its roots in musical tradition and performance art. Both traditions arrive at a synesthetic endpoint, mediated by space and time. There are however strong counter arguments in every case where sound sculpture made significant contributions to sound art and where experimental music contributed to *Klangkunst*, discussed earlier. A more important notion of the global relativism of sonic practice emerges. Within this context Wolfgang Welsch's book *Undoing Aesthetics* and particularly the chapter entitled "On the Way to an Auditive Culture" (1997) provides us with a more circumspect assessment of the emergence of sound art.

The text is situated within a philosophical and anthropological analysis of sound spearheaded by German musical journalist Joachim-Ernst Berendt, German authors Dietmar Kemper and Peter Sloterdijk and American author Marshall McLuhan. For Welsch, occidental culture, as framed by Classical Greek philosophy, particularly by Heraclitus and later reinforced by Plato, gave prominence to the eye over the ear as a more accurate witness. (Welsch 1997: 153) For Welsch, Heidegger is important. Heidegger saw a hearing culture as one of interrogation and caring relations. Listening is an act of inquiry and empathy, and sound functions as a catalyst for social interrogation and cohesion. These are two important themes that emerge in defining sound art through the lens of communication theory.

Welsch also signifies an important point in the process of defining sound art during the late 1990s and early 2000s, when there was a realisation that sound art could be studied as a branch of auditory culture. This triggered a proliferation of publications devoted to sound, the most notable being Douglas Kahn's *Noise, Water, Meat* (1999), a reissue of Barry Traux's *Acoustic Communication* (2000), Jonathan Stern's *The Audible Past* (2003), Christoph Cox and Daniel Warner's *Audio Culture: Readings in Modern Music* (2004), Brandon LaBelle's *Background Noise: Perspectives in Sound Art* (2006) and

Paul Hegarty's *Noise/Music: A History* (2007). This period, characterised by the rapid growth of a discourse on sound art, also stimulated the desire to define sound art in a more refined way. Hegarty captures some of the possible manifestations.

> Sound art takes many forms: sound installations, performances, recordings, whether for direct or public consumption or as purchasable object to listen to domestically, interactive pieces, pieces designed for headphone use, transmission of sound (often from other locations). Each of these has many variants. The sound source could be the most important factor or the process of listening it establishes. Sound art is not just sound working as art.
>
> (Hegarty 2007: 169)

By revealing the scope of sound art during the 2000s, Hegarty asks us to recognise the distinction between projection and reception. The medium is determined by the kind of listening that the work requires. Hegarty is suggesting that the various channels of sound should always be read as corresponding to a way of listening, the possibilities of which are innumerable. Hegarty notes many instances of sound art and the innumerable possibilities of transmission but fails to identify common characteristics and leaves this open-ended in the final sentence. More recently similar attempts to define sound art using a set of common characteristics were compiled by Maes and Leman, leading to the somewhat inevitable conclusion that sound art is a "hybrid category" (Maes & Leman 2017: 35) situated somewhere between visual art and music (Appendix: Item 1). Campesato, however, begins with the general principle that sound art emerged from both music and art, and in so doing establishes a set of criteria for what sound art is:

> Sound art differs from music and from other art forms in which sound plays an important role (cinema, for example) by establishing new possibilities of appreciation and listening. Its distinctive use of sound, the absence of a linear temporal discourse, the exploration of the referential potentialities brought by sound, the effective interaction between the audience, and the space and time in which the work occurs, all of these aspects collaborate to distinguish sound art as a discrete artistic modality.
>
> (Campesato 2009: 35-36)

Campesato then establishes three provisional criteria that she believes to be essential for the formation of sound art, namely the process, the reference and the context. The process questions how sound factors are employed in the creation of a work. The reference calls into question what the work is referring to and usually it is not a reference to a temporal narrative but to images, other sounds or the site. The context is often important in sound art and the architectural acoustics of the space often becomes an integrated element of the work.

From what I have discussed thus far, it is possible to take note of two recurring themes in the attempts to define sound art. The first is the tendency to define sound art either in accordance with the tradition of visual art or in accordance with the tradition of music. This point was made most explicitly when discussing Motte-Haber. The result is that the same phenomenon is referred to as sound art and *Klangkunst*. This is in part because, as this paper has shown, sound art emerged out of the convergence of two traditions, but also because there are regional differences in word usage that refer to the same object/concept, such as trunk or boot.

The second is the tendency to define sound art through a set of common characteristics. This is evident in how Maes and Leman resolve the question by calling sound art a "hybrid category" and similarly in how Hegarty states that sound art can take "many forms". The results are vague, perhaps because they are providing examples and not defining sound art as such. Cox recognises this ambiguity by calling sound art a "slippery and contested term" (Cox 2011: 86): not only does 'sound art' mean different things to different people, but these meanings are often cause for debate.

## A Working Definition of Sound Art

This definitional difficulty is not unique to sound art and a characteristic of art itself. The question "What is art?" is a prevalent and recurrent question in recent art historical discourse and it would be beyond the immediate scope of this paper to deal with the topic conclusively. Given the sheer scope of the question it is more beneficial for the immediate purpose of answering the question "What is sound art?" to draw from Tierry de Duve's recent formulation of the four uses of the word 'art'. In *Kant After Duchamp* (1996) de Duve's discusses how Duchamp's readymades signalled a shift from "this is beautiful" to "this is art". (de Duve 2019: 21) It also signalled a new purpose for art, one that "aspires to the destruction of the limits that condition its systems of traditional reception." (Celant 1981: 23) In the response to the position that art is whatever we call it, characteristic of institutional definitions of art, de Duve recommends a return to aesthetics. Below, a short overview of de Duve's four uses of the word 'art' is provided, which will form a backdrop for a discussion of what sound art is.

De Duve begins by suggesting that before Duchamp's readymades, whether or not a work could be art was based on the fine art system. Thus, sound art could not be considered as art because it did not fit within the system of traditional media. The post-Duchampian condition replaced the fine art system with the art-in-general (hyphenated and lower case) system by which all practices could be considered to be art – an "apparently infinitely liberal aesthetic regime". (de Duve 2019: 39) To consider a urinal as art presupposes the condition that anything could potentially be art. This potential for any material object to be art is what de Duve refers to as Art-in-General (hyphenated and capitalised). Importantly, because anything could potentially be art, a consequence of the art-in-general system is that it does not allow for anything *not* to be art. (de Duve 2019: 41)

The next use of the word 'art' that De Duve explains is art as such. This is the feeling, or more particularly the intuition that any Art-in-General object is art, thus art as such refers specifically to the aesthetic experience and is not a result of logic or reasoning. This intuitive judgment operates reflexively by the viewer comparing it to a collection of similar experiences, or in relation to what de Duve calls art altogether. (de Duve 2019: 43) As these experiences accrue, they form what classical aesthetics calls taste. To bring further elucidation to this comparative relationship between different experiences of art, it is useful to refer to Wittgenstein's idea of family resemblance:

> And the result of this examination is: we see a complicated network of similarities overlapping and criss-crossing: sometimes overall similarities, sometimes similarities of detail.
> 67. I can think of no better expression to characterise these similarities than "family resemblances"; for these various resemblances between members of a family: build, features, colour of eyes, gait, temperament, etc. etc. overlap and criss-cross in the same way.
>
> (Wittgenstein 1958: 32)

Importantly, even though art as such is drawn from a personal collection of art altogether, the judgment is "imputed to everyone". (Kant 1911: 53) The intuition that an object is art, even while drawing from subjective instances, is an appeal to what Kant calls the *sensus communis* – "a universally shared ability for sharing feelings universally". (de Duve 2019: 19) In simpler terms, the feeling that an object is art, although based on a subjective experience, is drawn from the assumption that everyone would also consider it to be art and thus, 'art' is a social construct. In Crawford's words:

> …the pleasure in the beautiful is not wholly subjective but has some basis that justifies our thinking that others should find the object beautiful as well, while fully recognising that not everyone will in fact agree with us.
>
> (Crawford 2001: 54)

This purported claim to the universality of aesthetic experience leads to de Duve's final conception, namely art itself. Because the feeling that an object is art has such an intimate relationship to the assumption that everyone will be able to agree, the natural conclusion is that all objects deemed to be art *ought* to share something in common. The idea that art objects *ought* to have something in common is art itself. (de Duve 2019: 49) In conclusion, when all four uses of the word 'art' congeal the overall postulation is that "Aesthetic judgement is a judgement that claims universal validity on the basis of a feeling in the name of an idea". (de Duve 2015: "This is Art")

If a comparison between what has already been established in this chapter is made with de Duve's four uses of the word art, a number of conclusions can be made. Firstly, the shift from the fine art system to the "art-in-general" system, signalled by Duchamp's *Fountain* (1917), would have included, at least in principle, sonic practices. The potential for any and all sound to be considered art was already in development in the form of a new tonal language or in the inclusion of everyday sounds and noises. Recording and playback technology also played a crucial role in understanding sound as a medium. Secondly, as the importance of sound became more widely recognised, due in part to spatial practices, experimental music and other related art forms, sound artworks as autonomous pieces became more commonplace. These works, beginning in the second half of the 20$^{th}$ century, helped to establish sound "art as such". Thirdly, the exhibitions mentioned earlier are evidence of the establishment of sound art altogether, in the last quarter of the $20^{th}$ century. Sound artworks had become numerous enough to become recognised within the mainstream canon of art. Lastly, the various efforts to define sound art are evidence of a search for common features of sound artworks in all its forms. In summary, the post-Duchampian condition allowed, in principle, for sound to be art. This inclusion, however, was contingent on technological developments. The early lexicon of sound art initially developed out of related art forms where sound was a secondary element of the work; the visual experience was primary and the sonic secondary. However, art that foregrounded sound and auditory experience, supported by technological developments, provided the ideal conditions for sound art to become named and recognised.

In the previous section an overview of the attempts to define sound art was given. There was a tendency to define sound art either through the tradition of music or the tradition of visual art. This chapter has shown how naming a work of art 'sound art' necessarily acknowledges these two convergent traditions. What emerged when locating sound art in relation to de Duve's writing was the transition from sound as an incidental part of an artwork to sound as the fundamental part of the experience of an artwork. This is an important insight and leads to the working definition that this dissertation will assert, that:

> *Sound art is a form of art that foregrounds sound in relation to the experience of time and space*.

Thus, for artworks to be considered as sound art it is necessary for them to produce sound. The foregrounding of the sound means that if the work does have a visual element, it is in support of the auditory experience. Thus, any conception of a work of art as sound art, beginning with sound as primary, is inextricably linked to the experience of time and space – dealt with more specifically in Chapter 5.

# CHAPTER 4: SOUND IN THE PHYSICAL WORLD

In previous chapters I discussed the evolution of the human ear and hearing, and noted that music evolved out of the need to communicate and reinforce social bonds. It became evident that music underwent major development and expansion of its technical abilities in the course of the centuries. Sound art drew greatly from music and the possibilities for doing so accelerated in the latter part of the twentieth century, with the growth in audio technology. The shift in art towards the dematerialised art object, site specificity and the relationship between art and spatial practice encouraged artists to work with sound, and out of this came the phenomenon known as sound art. The question of what sound art is, remains an occasion for debate, and this is likely to continue given the proclivity of sound work to overlap with related art forms. Even though sound art tends to elude fixed definitions I can begin to discuss it more systematically by beginning with an understanding of sound itself. That is what this chapter will aim to do: refine our understanding of sound itself. There are two major facets of this explanation, that of physics and that of neurobiology. Anyone interested in sound art should ideally be aware of the scientific foundations of sound and hearing. It is important to note that these fields are beyond my area of expertise, therefore this chapter draws on research that cannot be my own.

The common-sense definition of sound is that it is what we hear and what we do no hear is therefore not sound. This is a fallacy of improper transposition. Thus, in this chapter I will speak of sound, in the physical world, to include that which we do NOT hear. The first part of this chapter assembles our knowledge of the physics of sound within the context of matter and energy in order to establish what sound actually is before it is heard. An experiencing subject is then introduced to this vibratory field with the introduction of the biological mechanisms of hearing. This fundamental understanding of how hearing works would not be complete without acknowledging the medium to which our hearing is tuned. Accordingly, the remainder of the chapter focuses on how environmental factors shape hearing.

## The Mechanics of Sound

> Sound energy is generated when a medium is disturbed by particle motion. This disturbance generates pressure variations in the medium. These pressure variations travel in patterns associated with the medium conditions and dissipate as they expand from a local source over an increasingly larger area.
>
> (Cowan 2016: 1)

> The microscopic world impinges on the macroscopic…
>
> (Lautrup 2005: 3)

Everything in the universe consists of matter and energy. All matter is in a state of motion and the forces that underpin this motion, as first identified in Newton's three laws of motion. Newtons laws are well documented but because they are so important, I will make mention of them.

1. The law of inertia states that an object at rest will tend to stay at rest and an object in motion will tend to stay in motion unless acted upon by a force, and that objects that have more mass have more inertia.

2. The law of force states that the force of an object is numerically equal to the mass of the object multiplied by its acceleration.

3. The law of action and reaction states that for every action, there is an equal and opposite reaction. If a force is exerted on an object, the object exerts an equal force back; this perpendicular force that gets exerted back is known as the normal force.

Whereas weight is the force of gravity and is measured in Newtons, kilograms are the measure of mass. For example, gravity pulls my chair to the floor on which it stands, and the floor exerts a force back in a perpendicular direction onto the legs of the chair, and, as a result, the net force is zero.

The concepts of measurement that are brought to the fore through Newton's laws of motion fall into two categories, namely vectors and scalars. Vectors measure direction and magnitudes such as velocity, force, work, power and acceleration. Scalars have no direction and measure magnitudes such as mass, temperature, speed, distance and time. (Cassidy et al. 2002: 453-455)

What I am attempting to explain in this chapter, among other things, is time in the objective sense, with reference to a mechanical view of the world. In this sense, I am referring to absolute time. (Disalle 2006: 20) This is non-relativistic, independent of perception and, quite simply, what the clock reads and thus is sufficient for us to measure time in seconds. The same can be said for length. Length is what the rulers measure and thus it is sufficient for us to measure length in metres. For the time being it is not worth getting into any real depth about the nature of measurements other than to indicate that they pertain to the classical mechanical world-view within the language of applied dynamics. The language of classical mechanics and the phenomena that it describes lays the very foundation for how sound is understood: without these units of measurement it would be impossible to understand sound and vibration. This also means that the mechanics of sound in the way that it is understood today, is still fairly recent and based on the fundamental measurement of mass, distance, time and temperature.

The behaviour of atoms and molecules is quantifiable and based on a set of principles related to the degrees of freedom they have, as determined by their chemical bonds. Their motion is a result of kinetic energy or heat energy. At absolute zero, or -273.15 degrees Celsius, there can be no molecular motion; at any temperature higher than this, all molecules are in a state of constant flux. At an intermolecular level, the nature of the motion between molecules determines whether a substance is a solid, liquid or a gas. Or to put it differently: the amount of kinetic energy between molecules is what determines the state of the particular substance, be it solid, liquid or gas. Whereas there is very little kinetic energy between the molecules of a solid, there is more kinetic energy between molecules of a liquid, and lots of kinetic energy between the molecules of a gas. The more heat is added to a substance the greater the excitation of the molecules. Because of this, phase changes can occur where the substance transforms from a solid to a liquid and finally to a gas. (Tivoni, no date: The Invisible Motion of Still Objects)

All substances on earth, or substances within a given system, have mass and volume. The mass of a substance is the amount of matter within the space it occupies, and the volume is the amount of space occupied by the matter. Together, both mass and volume determine density such that mass and density are proportional to each other; thus, if the volume is decreased the density will increase. This can only occur if an external force acts on the system; if no external force acts on the system then the system is said to be in its natural state. (Lurie 2005: 29) Whereas an external force exerts an action on the system, the internal force is the natural state of the system, which means that the force measured at any arbitrary location within the system will be the same. (Lurie 2005: 32) An external force does work on the system and energy is the ability to do work.

The energy in the universe itself is never lost and no new energy can be created; it is simply transformed from one form to another and is thus conserved. There are two types of energy and each type has various manifestations. Kinetic energy is the energy "possessed by a body due to its motion" (Jain 2009: 9) and manifests itself as mechanical, electric, thermal, radiant and acoustic energy, for example. Potential energy is the energy "stored in a body or system due to its position in a field of force or due to its configuration" (Jain 2009: 10) and manifests itself as chemical, atomic, gravitational and elastic energy, to name but a few. It is not difficult to observe how energy manifests itself or how one form of energy transforms into another and examples are all-pervasive. For the time being it is useful to do no more than recognise the distinction between kinetic and potential energy.

Fundamentally, force is the ability to do work. Not all forces do work; energy is needed for them to do so. Energy is not an observable quality, rather, it is a potential or kinetic quantity contained in a system when a force does work. Energy is therefore a measure of properties external to itself. For example, if a person were to push a box that has a mass of one kilogram along a frictionless plane for a distance of one metre, the person contains a certain amount of potential energy. This energy is transformed into kinetic energy when he/she does work on the box and it moves. The amount of work is a measure of the net force multiplied by the distance and is measured in newton-metres. The amount of work is translatable into joules – the measure of capacity to do work. Thus, the amount of energy it took for the person to push the box was one joule by a force of one Newton over a distance of one metre. (Brosing & Griffith 2009: 104)

In order to understand motion, it is useful to first understand force. The interaction between bodies result from either a push or a pull that produce a change in the state of motion. (Jain 2009: 1) Forces can either act at a distance, as do gravity, magnetism and electric forces, or they can act by way of contact. Forces have magnitude, direction and a point of application, all represented by vectors. Vectors are anything that has magnitude and direction. A contact force in the case of collision, tension or friction exerts pressure on the surface of the object. The sum of all the forces, internal and external, of the given system is the net force, and the net force results in an effect, which could possibly change the shape of the system or the motion of the system.

For our purposes, there are two important facts about substances, namely their stiffness or rigidity and their density. The former, often called bulk modulus, is measured in Pascal, and refers to how much pressure is required to compress a given volume of a substance, its volumetric elasticity. The density of the material refers to the mass per volume of the given substance and its measure is called the Row. In 1738, Daniel Bernoulli showed that the pressure is proportional to density, provided that the temperature is constant. (Cassidy et al. 2002: 302)

It is worth noting that a less elastic substance with a large bulk modulus has a more highly interconnected molecular structure than a more elastic substance with a small bulk modulus. As a result of the level of molecular interconnectivity, the transference of energy from one molecule to the next happens more readily when a substance is more rigid and less readily when a substance is less rigid. The energy transference in relation to density happens in opposition to the rigidity of the substance. A dense substance has more mass than a less dense substance. The more mass a substance has, the more inertia it has and the more resistant to change it will be. The denser the substance the less likely it will transfer energy from one molecule to the next. However, in general, greater rigidity of a substance will compensate for an increase in density. As a result, intermolecular energy transference happens more readily in a solid than in a liquid and more readily in a liquid than in a gas.

A given area of three-dimensional space can itself expand and contract by virtue of the temperature of the given substance. The three-dimensional space to which I refer is called a system. A system is a "macroscopic entity extending in space and time and accessible to normal processes of measurement". (Quinn 1990: 2) A further factor influencing the behaviour of a system is that the entities which are contained within the system are interconnected and interdependent – the parts affect the whole. (Neal 2016: 1) There are many kinds of systems but for our present purposes I will be referring to a system in a state of thermal equilibrium. Here, a distinction must be made between heat and temperature. Whereas a *process* variable is a measure of change when an external force such as heat or work acts on a system, temperature is a *state* variable and the measure of the average kinetic energy of a dynamic system, such as a system of air. Heat always moves from a system with a high temperature to a system with a low temperature. When I speak of a system in a state of thermal equilibrium, no heat is being gained or lost; the molecules within the system will maintain their ordinary state of motion. (Quinn 1990: 3)

An extension of the distinction between heat and temperature is the distinction between pressure and density, which I will make shortly. First, it is important to understand the relationship between temperature and pressure. When there is an increase or decrease in temperature, there is an increase or decrease in pressure; and when there is and increase or decrease in pressure, there is an increase and decrease in temperature. This correlation was discovered by Joseph-Louis Gay-Lussac (1778-1850). (Cassidy 2002: 297)

Therefore, when I cool down a cube of iron, it contracts and when I heat it up, it expands. Furthermore, pressure is a factor. The more pressure on a given system the higher its temperature. As a result, the transference of energy from one molecule to the next happens more readily in dense substances and substances under a greater degree of pressure than the transference of energy in a less dense substance or a substance under less pressure.

The physical world is undoubtedly filled with sound. The inherent vibration of matter on the smallest imaginable scale shows that much of the nature of the physical world is intrinsically sound-like. On the microscopic scale, even though objects appear stationary, the smallest elements of their existence are alive with vibratory energy beyond our field of perception. How this microscopic world impinges on the macroscopic becomes evident when, for example, I think about the expansion and contraction of a corrugated iron roof. Iron is a good conductor of heat. As the thermal energy of the sun is transferred to the roof, the iron molecules vibrate with a higher degree of kinetic energy and the roof expands. As is expands, it buckles and what is audible is this microscopic motion in action. Later in the afternoon, it loses its thermal energy and contracts. This pulse of expanding and contracting is the very day-night rhythm of vibration, defined by the sun and to which all matter is subjected.

To illustrate the degree to which objects in our environment are subject to continuous oscillatory motion, the example of video vibrometry is ideal. Ordinary video records minute changes in light and motion, but video vibrometry works by magnifying these changes in light and motion to make them visible to the naked eye. These magnified fluctuations in light and motion can be used to make visible the swaying of a crane in the wind, the pulse of blood on your wrist or any changes in light or motion that would not ordinarily be visible. Magnification of video has also been used to translate the changes in light and motion into sound. In the experiment, an empty potato chips packet is filmed, and the experimenter plays a tune. Although the chips packet appears to be stationary when the tune is played, the video microphone is able to record the invisible motions of the packet that result from the vibrations cause by the playing of the tune. When the magnified video is then converted into sound it is evident that the tune resonated through the chips packet. In this sense the chips packet became a microphone. The same experiment was conducted on an indoor plant and as a result it is safe to assume that our entire environment could potentially become a microphone. (Davis et al. 2017: 732-745)

In summary, I have defined the nature of our physical and chemical environment both on a microscopic and a macroscopic scale. Small components combine to form larger ones that are call substances. When speaking of a given area of a substance, it can be called a system, continuum, material or medium. The system has mass, volume, density, elasticity and temperature. External forces act on the system and this is called work.

## Sound Waves

Now that a brief understanding of the quantifiable variables that exist as a result of the physics and chemistry of our environment has been established, it is useful to apply this to the nature of sound. In order to understand the nature of sound, an understanding of periodic motion is essential. Remember that the fundamental marker of our physical description is that all matter on a microscopic level is in a state of motion. Much of this motion is vibratory, and the nature of the microscopic world bears upon the nature of the macroscopic. To present an accurate account of periodic motion, I need to freeze time, so let us imagine a snapshot of the environment.

If I were to postulate a body in its equilibrium position and wish to account for its state, I can say that it is hypothetically stationary and call its position its *mean* position. Periodic motion is either rotational or oscillatory; our focus will be on the latter. Oscillatory motion is also often called vibratory motion. Let us now travel one second forward in time from our snapshot and suppose that the mean position of the body has moved one centimetre to the right. An external force acted upon the body and the body transformed its energy into kinetic energy. What that external force is, is not important at the moment but, as I have already noted, the body would have resisted being moved. Moving another second ahead, the body returns to its mean position. The force that returns it to its mean position is called the restoring force. (Jain 2009: 21-22) If in this case the restoring force is greater than the initial force that made it move to the right, the kinetic energy of the restoring force will cause the body to overshoot its mean position. In this scenario, let us imagine that it overshoots and travels one centimetre to the left. Going forward another second in time, the restoring force once again acts upon the body to restore it to its mean position. What the example illustrates is a repetition of potential energy being converted into kinetic energy and back into potential energy. (Brosing & Griffith 2009: 115)

This back and forth movement of a body around a mean position is the essence of oscillatory motion and is our starting point for understanding vibration and, therefore, sound. Primarily there are two necessary attributes that a body must possess in order for oscillatory motion to be possible at all. The first is inertia. A body with more inertia is more massive and denser and therefore the transference of kinetic energy from one molecule to the next will be less likely. The second is elasticity. The more rigid a body, the more likely it will transfer kinetic energy from one molecule to the next. The two conditions are interrelated and to recall an earlier discussion, it is usually the case that an increase in rigidity compensates for an increase in density. (Karczub & Norton 2003: 1)

Given the preconditions of inertia and elasticity, I must now clarify what is meant by the transference of kinetic energy in an elastic medium with mass. When an external force acts on a system its energy is transformed by the system into kinetic energy in a sequential fashion. The first molecule collides with the second, causing the second to collide with the third and so forth. Dependent on the variable elasticity and inertia of the substance in question, in a vibrating system the collisions will happen in reverse order, too, causing the back and forth motion mentioned earlier. The kinematics of this vibratory phenomenon is influenced by two factors. The first is the rate at which the molecules move back and forth along the mean position and the second is the rate at which the transference of collisions along the sequence of molecules occurs. The most accessible manner in which to articulate the distinction between the two is to describe them as graphs. The first is the displacement versus time graph and the second is the displacement versus position graph.

For the purpose of this description, let us refer to simple harmonic motion in which the system in question vibrates at regular intervals. (The different types of wave motion will be discussed later.) The simplest way to describe this is to imagine a ball attached to a horizontal spring on a frictionless plane. When the ball is stationary it is in its equilibrium position. If I were to move the ball it will oscillate along its initial position, reversing its motion at lengths that are equal to each other on either end, which is called the turning points. In this case the distance between the equilibrium position and either turning point is the same and is referred to as the amplitude. In this example, all of the system's energy comes from the spring. When it passes through the equilibrium position, its potential energy is zero, but its kinetic energy is at its greatest; when it is at either turning point, its kinetic energy is zero, but its potential energy is at its greatest.

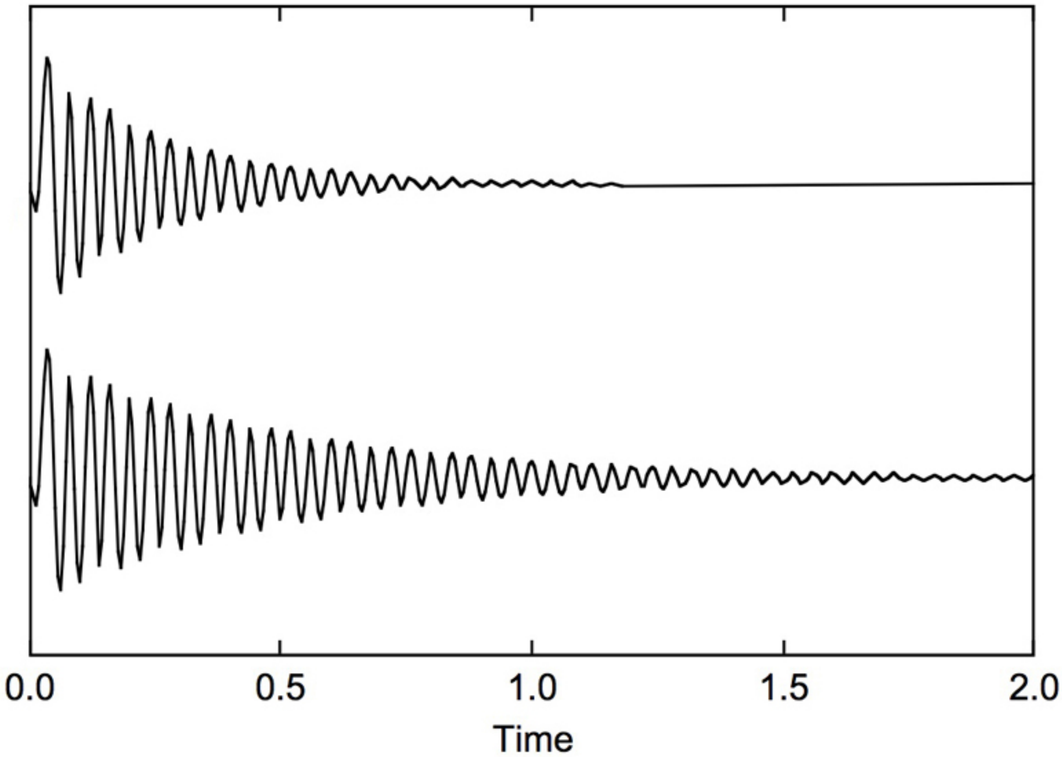



**FIGURE 6: Howard, D.M. & Angus, J.A.S. *Direction Versus Time Graph* (2009)**

Figure 6 from Howard & Angus represents the displacement versus time graph of dissipating sound. The vertical axis represents the distance from the equilibrium position that the air molecule moves in relation to the horizontal axis of time. In relation to harmonic motion, the graph will generate a sine wave or sinusoid mathematical curve. Here, the peak of the sine wave represents the rightmost position of the molecule and the trough of the sine wave the leftmost position of the same molecule. Whereas at the onset of the graph the distance from the equilibrium position is at its furthest and the sound is at it loudest, as the sound gradually dissipates the distance from the equilibrium position varies less and the sound becomes gradually softer. The distance between the equilibrium position and the peak as well as the distance between the equilibrium position and the trough is called the amplitude. The more external energy is transferred to the system in question, the greater the displacement of the molecules and therefore the higher the amplitude will be. Furthermore, the time it takes for the molecule to move back and forth and return to its equilibrium position is called a cycle and the distance between peaks is the called the period. More explicitly, this graph shows how quickly a particular molecule moves back and forth. The closer the peaks are to each other, the higher the frequency of the vibration; the further the peaks are the lower the frequency of the vibration.

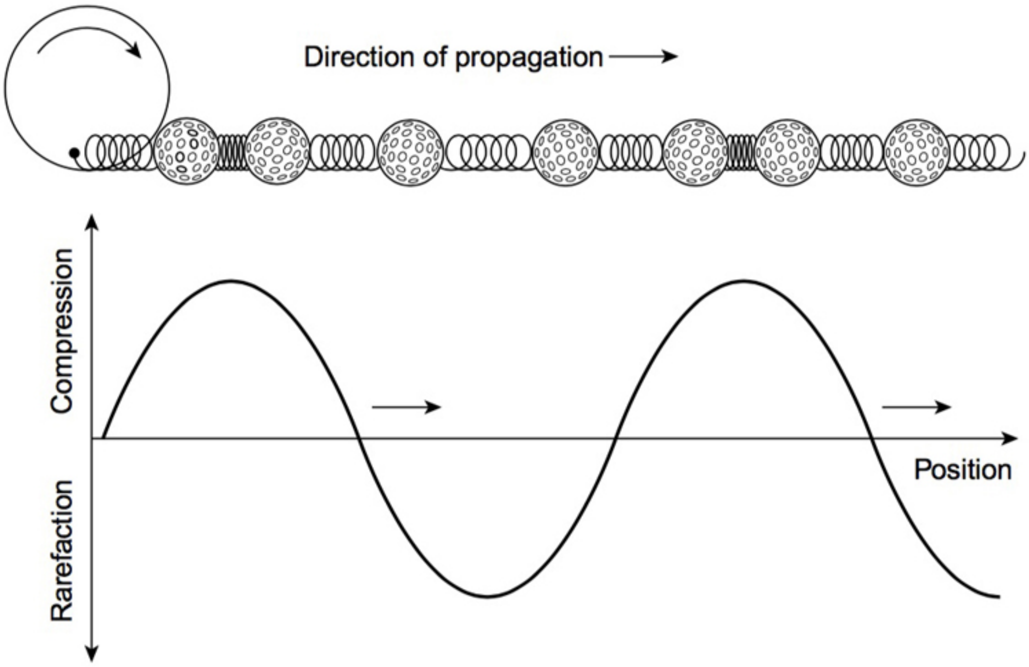



**FIGURE 7: Howard, D.M. & Angus, J.A.S.** ***Displacement Versus Position Graph*** **(2009)**

Figure 7, also from Howard & Angus, accounts for the sequence of event that unfolds as a result of the transference of intermolecular kinetic energy and illustrates this with a golf ball attached to a spring – the spring is like sound, and also is a longitudinal wave. In this instance, we are still referring to simple harmonic motion and the graph still articulates itself as a sine wave. The graph represents displacement versus position and provides a snapshot of where all the air molecules along the wave are at a particular instant in time. In this graph we can see compressed regions of molecules and rarefied regions of molecules. Importantly, the distance between two peaks in this graph is the wavelength, which means quite simply the distance between two compressed regions of air.

It is important to take note that I have been speaking about finite systems in a state of equilibrium, with a single degree of freedom, and that I will continue to do so. However, it is worth explaining the distinction between finite and infinite systems in relation to natural frequencies. Whereas an infinite system can vibrate at any frequency, natural frequencies are properties only of finite systems. (Karczub & Norton 2003: 2)

By way of example, consider a girl on a swing being pushed by her brother. The girl, the swing and the tree from which it hangs, is a finite system. Her brother is the external force. The height which the swing reaches in its back and forth motion is its amplitude, the rate at which she reaches either extreme is the frequency and the time it takes for her to complete one cycle is the period. If the external force ceases to act on the system, there will consequently be a loss of energy within the system. In other words, the momentum of the swing will work against the opposing force, in this case friction; it will lose its energy and amplitude over a given period of time, in a process that is called damping. In theory, I could remove the opposing force that causes damping and remove the external force and allow the girl to swing freely and perpetually. She will be in a state of free vibration and be swinging at a rate that is recognised as the natural frequency of the system and self-sufficiently swinging as a result of the internal forces within the system. (Karczub & Norton 2003: 10)

There are two primary waveforms, namely S-Waves or transverse waves and P-waves or longitudinal waves, that are important for understanding the vibrational phenomena of our environment and how they manifest themselves as a consequence of the properties of a given system. To explain the variations in waveforms let us visualise a continuous system that consist of either solids, liquids or gasses. As I mentioned earlier, solid-state substances have strong intermolecular bonds. As a result of the strength of these bonds, solid-state systems can store energy in various forms and thus both transverse and longitudinal waves occur simultaneously for any vibratory event. (Karczub & Norton 2003: 193) In liquids, both transverse and longitudinal waves coexist but longitudinal waves predominate to a large degree and in gasses only longitudinal waves occur. (Bruneau 2006: 16)

The fundamental difference between the two different waveforms is the manner in which they propagate through a continuous system. Whereas S-waves travel perpendicularly through the medium, P-Waves travel longitudinally. For example, if I tie a rope to a fixed point at one end and move the other end up and down at a constant frequency, this is an S-Wave. However, if I were to tie a spring to a fixed point at one end and move the other end backwards and forwards, this is a P-Wave. Waves that travel through the atmosphere are P-waves.

## The Biological Mechanisms of Hearing

In response to the intricacies detailed above, it is safe to argue that oscillatory vibrations, the kind that make sound audible to us as a species, exist in multiple forms outside of the field of what is audibly perceptible. These are sounds not heard. From minute atomic vibrations to tides that ebb and flow, from the smallest measurable seismic rumbles to the expansion and contraction of the massive concrete structures of the built environment, these vibrations are, in their barest essence, sound-like. Our window of perception is tuned to a very narrow bandwidth in relation to the vastness of what exists in actuality. However, it is important to narrow down our search for sound and make a number of important exclusions: vibratory phenomena that would not be perceptible without amplification, and perceptions of sound that were not caused by some soundmaking entity in the environment, as in the case of auditory hallucinations. In what follows, it is important for us to discuss only how sound events reach our ears and become converted into that which we perceive as sound.

There are two key concepts that are important for understanding the ability to hear sounds, namely loudness and frequency. What follows will present a very generalised discussion of human hearing in relation to very idealised environmental conditions. This is commonly referred to as "normal human hearing" and, for the time being, I will not factor in any environmental variables that influence the nature of sound. Here, the environment is purely hypothetical.

### *Loudness*

Loudness is measured in decibels, written dB, often signified with beta or β**.** How the decibel is arrived at is more easily explained if the formula is broken into individual elements. The first element is 10 multiplied by log to the base number 10. The first 10 here represents the fact that I am speaking of the decibel scale. If I were to leave out this 10, I would be speaking of the bel scale but as a mere matter of convenience, and to avoid decimal points, loudness is described in decibels where one decibel is 10 times 1 bel. Log is a mathematical device that is used to make very small numbers or very large numbers more manageable. Simply stated, log is how many of one number is multiplied to get another number. The base number represents the number that is being multiplied. For example, $log_2(8)=3$ is a mathematical way of saying that the number of twos needed to get eight is three. It is standard to use 10 as a base number in the decibel scale, thus the first element of our formula is written $10log_{10}$.

The second element of our formula is intensity. I spoke earlier about joules being a measure of energy and power. The rate of work, measured in watts, is the number of joules per second. Intensity extends upon this as the amount of power per given area, in this case a square metre. So essentially, the second element of our formula refers to the number of joules that pass through a square metre of a system within a second.

The third, and probably most intriguing, element refers to the threshold of human hearing, the smallest audible sound. What is intriguing is that, as a species, human beings are capable of hearing surprisingly soft sounds and this part of the formula is a representation of that minute value and is written as $10^{-12}\, W/_{m^2}$ mathematical shorthand for the value 0,000000000001 watts per metre squared, also known as a picowatt or pW. At this point, 1 picowatt per square metre is the equivalent of 0 bells and because of the kind of logarithmic scale being used, a sound that is 1 decibel is 10 times more intense than 0, and a sound that is 2 decibels is 10 times more intense than 2 decibels or 100 times more intense than 0 bells, and so forth.

There is no upper end to this scale of volume, but it is commonly assumed that the loudest sound occurs at the level at which it causes discomfort. This is $1\, W/_{m^2}$
It is precisely because the scale between the threshold of human hearing and the point at which sound causes discomfort is so large, with 12 orders of magnitude separating the lowest and the highest number, that the logarithmic tool is used. That being said the final formula arrived at is written as follows:

$$\boldsymbol{\beta = 10log_{10}\left(\frac{I}{10^{-12}\, W/_{m^2}}\right)}$$

Now that this has been established, it is possible to use the amount of sound power passing through a metre squared within a second to determine its loudness in relation to the threshold of human hearing. For that matter, when the number of decibels of a given sound is known, this can be used to work out the sound’s intensity. Putting what has been established into practice, that increasing the volume of a sound makes it louder, is known. This means that the amplitude of each wave is greater and as a result the amount of force it exerts on the molecules in a given area also is greater. The intensity of a sound is a measure of how much sound energy has passed through a square metre within a second. The decibel scale is an expression of how this relates to the threshold of human hearing.

| dB | Intensity | Example |
|---|---|---|
| 0 | $1x10^{-12}$ | Threshold of Human Hearing |
| 10 | $1x10^{-11}$ | Leaves |
| 20 | $1x10^{-10}$ | Whisper |
| 30 | $1x10^{-9}$ | Quiet Home |
| 40 | $1x10^{-8}$ | Average Home |
| 50 | $1x10^{-7}$ | Average Office Soft Music |
| 60 | $1x10^{-6}$ | Normal Conversation |
| 70 | $1x10^{-5}$ | Traffic |
| 80 | $1x10^{-4}$ | Loud Radio |
| 90 | $1x10^{-3}$ | Inside Heavy Truck |
| 100 | $1x10^{-2}$ | Noisy Factory |
| 110 | $1x10^{-1}$ | Damage |
| 120 | 1 | Loud Rock Concert |
| 140 | $1x10^{2}$ | Jet Airplane |
| 160 | $1x10^{4}$ | Bursting Eardrum |

### *Frequency*

The second condition of our auditory window is frequency, a concept familiar to us from an earlier discussion. Here, however, the concept of Hertz will be introduced. To look at a basic sine wave, charted on a graph: the time that a molecule takes to travel from its equilibrium position to one extreme position, back past its equilibrium position to the opposite extreme position and then return to its equilibrium position is called one cycle. The amount of time that it takes for the molecule to pass though one cycle is its frequency, the speed of its oscillation. The frequency of a sound is heard as pitch. The lower the pitch of a sound, the more time it takes for one cycle to be completed and the higher the pitch of the sound, the less time it takes for one cycle to be completed.

It is important to understand that the speed of the oscillations have nothing to do with the speed of the sequential transfer of energy from one molecule to the next on a longitudinal plane; it is merely the rate of the back and forth motion of molecules. The unit used to describe the number of cycles in a second is Hertz or Hz and is often used as kilohertz or kHz.  A sound that is 1000Hz completes one full cycle in a thousandth of a second or a millisecond. The spectrum of what is audible to human hearing is generally between 20Hz and 20kHz. Anything below 20Hz is called an infrasonic sound and anything above 20kHz is called an ultrasonic sound. A higher frequency sound of the same loudness will not travel as far as a low frequency sound and will dissipate more readily. Low frequency sounds also travel more readily through denser material, whereas high frequency sounds travel less readily in dense material and more readily in less dense material. When considering sound frequencies in relation to what is audible to human hearing, returning to an earlier proposition is inevitable: that hearing essentially evolved in partnership with speech and therefore its primary purpose is communication. (Lieberman 2011: 395)

As unreliable as they might be, the primary purpose of our senses is to provide us with knowledge of states of affairs in the world that people inhabit. The most immediate sense to us is that of touch. Touch relates to what is reachable, within our grasp, and is a realm of tactile agency in close proximity to personal space. (Purves 2018: 2) It is also somewhat of a primordial membrane between the outer world and what is contained within our body, giving us the basic morphemes for sensing ourselves. There is an immediately evident diversity to the range of sensations related to touch, but it is most likely that these sensations are, in their crudest form, related to that which is near. Later, I will briefly examine touch as a foundation for our understanding of hearing, using the tactile route to the audible, the here and now as a point of reference to the there and now.

## *The Neurobiological Process*

The nervous system functions in three stages: sensory input, integration and motor output. The system itself is divided into the central nervous system, comprised of the brain and spinal cord, and the peripheral nervous system, comprising all the nerves that branch off from the central nervous system. The peripheral nervous system consists of two parts, the efferent division that sends signals from the central nervous system to the rest of the body, and the afferent division that sends signals from the rest of the body to the brain. (Noback et al. 2005: IX) I will look closely at the afferent division of the peripheral nervous system, beginning with the primary building block of the nervous system, the neuron.

There is a variety of different neurons, but they all share a basic physiology, consisting of the cell body or soma, axons and dendrites. Both the axons and dendrites are called processes, which are basically neural projections extending from the cell body. The number of processes that a nerve cell has is what distinguishes one type of nerve cell from the next, and they differ in function. We are most likely to be familiar with multipolar neurons, which consist of a single axon and many dendrites. What is more important to understand is that the dendrites receive neural messages and the axons send neural messages. (Noback et al. 2005: 11)

When one neuron is stimulated, it sends a signal down the axon to the next neuron. This signal does not vary in strength and speed but only in frequency. It is much like a binary code: 0 means that the neuron does not fire and 1 that it does. The key to understanding how this works is by understanding action potentials, which are related to both a chemical and an electrical process. When a neuron is not firing, the neural area is electrically neutral; it is said to be at its resting potential. The inside and the outside of the neuron is separated by a membrane. The outside of the neuron is surrounded by extracellular fluid, also called interstitial fluid, and the inside of the neuron contains intracellular fluid or neuroplasm. (Noback et al. 2005: 41)

The overall charge of the neuroplasm is negative and the overall charge of the interstitial fluid is positive. This electronic charge is a result of the number of either positively charged ions called cations or negatively charged ions called anions on either side of the cell membrane. (Siegel & Sapru 2011: 78) At its resting potential, there is a higher concentration of positively charged sodium and negatively charged chloride ions in the interstitial fluid than in the neuroplasm and in the neuroplasm there is a higher concentration of positively charged potassium ions and negatively charged organic proteins. The potential energy that these two separate charges generate is between 60 to 70 millivolts. (Noback et al. 2005: 43). The polarisation of this charge is regulated by proteins that are part of the membrane, the most important of which is located in the sodium-potassium pump that is found along the axon. It regulates the charge of the interior and exterior of the cell by pumping three sodium ions out of the neuron for every two potassium ions it pumps in. This regulatory function of the sodium potassium pump creates an electrochemical gradient – a difference in the concentration of the number of ions and consequently a difference in the charges between the interstitial fluid and the neuroplasm.

In addition to the sodium-potassium pump there are many different kinds of ion channels but the only other of equal importance to us here is the voltage gated channel. Voltage-gated channels open and close in response to a change in voltage. At rest, the voltage-gated channels are closed, and the 70-millivolt gradient is maintained. If a small amount of sodium enters the cell, there will be a small increase in the voltage. This is called a graded potential where the change in voltage is not large enough to trigger the voltage-gated channels. However, if a larger amount of sodium enters the cell and the change in voltage is large enough to trigger the voltage-gated channels, it creates an action potential. (Noback et al. 2005: 45) It is important to note that if the change in voltage is not large enough, there will be no action potential and the neuron will not fire. The threshold for this change is an increase of approximately 15 millivolts. (Noback et al. 2005: 48) When voltage-gated channels open, ions diffuse into the cell and it becomes depolarised. This depolarisation triggers a chain reaction along the membrane, causing the electrical current to travel along the axon. As soon as this process is complete, the membrane repolarises itself. The strength of the action potential between the point of stimulation and the end point is not dependent on the weakness or strength of the stimulus. As I have already mentioned, it depends on the frequency of the neural firing. The rate at which neurons fire creates a code that is decoded by the brain and interpreted as either a weak or strong stimulus. (Noback et al. 2005: 48)

Neurons themselves could not operate in isolation. When an action potential fires it travels from one neuron to the next, following a route tailored to the next. This interconnectedness is why it is called a nervous *system.* There is an important mechanism that functions in the transmission of a message from one neuron to the next: the synapse. When an action potential travels down the axon of the presynaptic neuron, it reaches a network of terminals that are either connected to dendrites of the postsynaptic neuron or to the cell body of the neuron itself. The presynaptic terminal contains vesicle sacs that store neurotransmitters. The neurotransmitters are released, spreading across a small gap called the synaptic cleft and binding on particular receptor sites on the postsynaptic neuron which, once again, causes its ion channels to open and causes another action potential in the postsynaptic neuron. The neurotransmitters might excite or inhibit the postsynaptic neuron depending on the type of neurotransmitter that is released. (Siegel & Sapru 2011: 96-98.) (For a comprehensive list of the different types of neurotransmitters and their functions see Siegel & Sapru 2011: 108-131)

### *Touch*

As part of the integumentary system, our skin is composed of three layers: the epidermis, the dermis and the hypodermis (subcutaneous fat). Together they form a stratum of sensation that 'listens' to its environment and locates the body in a gesticular present; it is a system that is subject to external forces. Of immediate relevance to us is cutaneous sensation and, in particular, tactile sensation. There are four sensory receptors located in the region between the dermis and the hypodermis: Merkel receptors, Meissner corpuscles, Ruffini cylinders and Pacinian corpuscles. They are sensitive to different frequencies and vary in density throughout the body. Merkel corpuscles are sensitive to frequencies between 0.3-3 Hz, Meissner corpuscles to between 3-40 Hz, Ruffini cylinders to between 15-400 Hz and Pacinian corpuscles to between 10-500 Hz. (Herman 2007: 79-80) Together, this establishes a frequency range between 0.3 and 500 Hz which is 'heard' by our skin. If I compare that to the 20 Hz threshold of hearing, it is clear that there is a low frequency, infrasonic acoustic domain that is heard not with our ears but with our bodies. This is not only a result of the sensitivity of the surface area of our skin but also of our body's orientation in space, as illustrated by Karczub and Norton below:

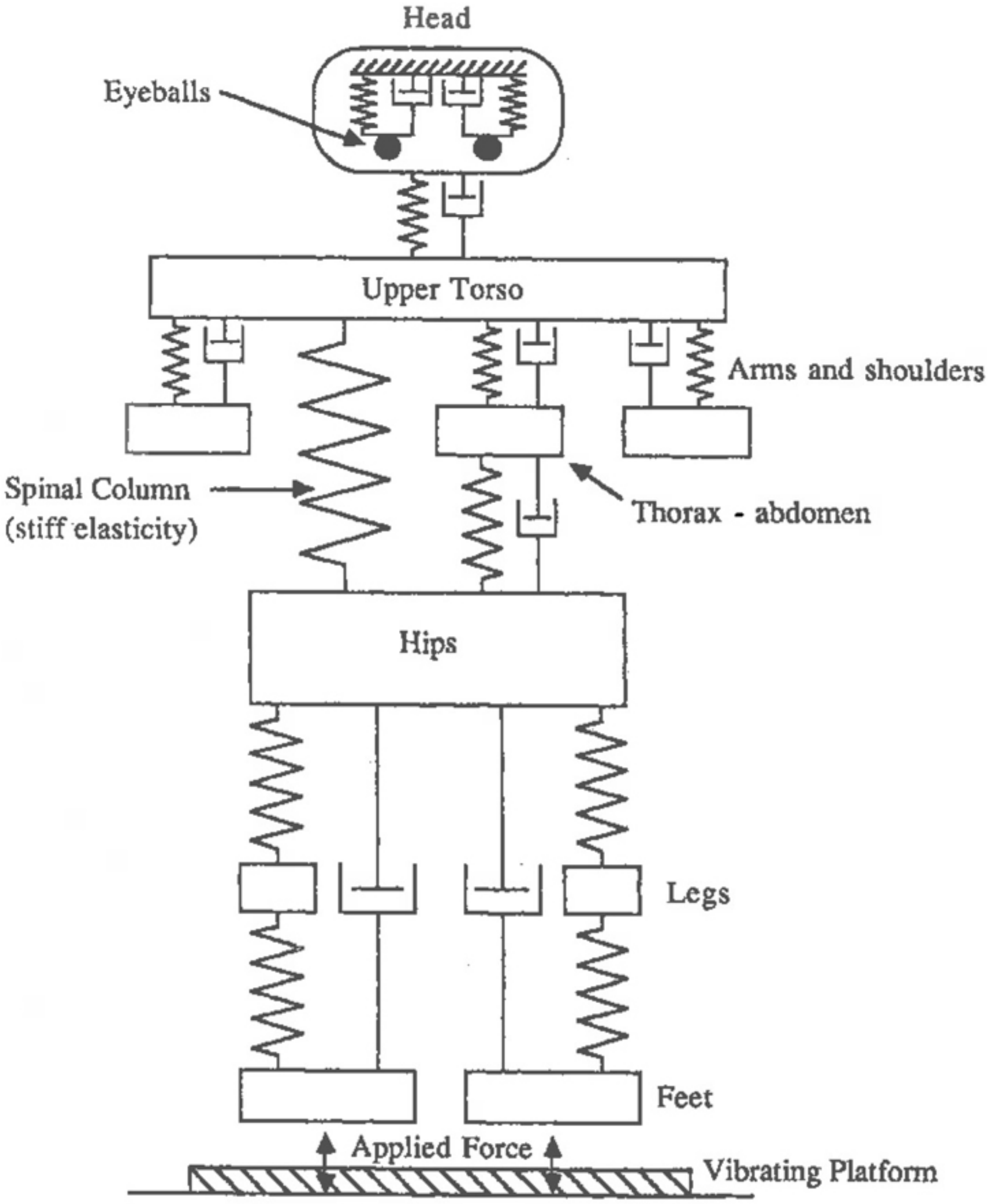



**FIGURE 8: Karczub, D.G. & Norton, P.** ***A Simplified, multiple, discrete mass-spring-damper model of a human body standing on a vibrating platform*****. (2003)**

The sensitivity of the realm of touch as a medium for experiencing the vibratory environment is a very direct way of understanding the subjective domain of our being in the world. The oscillations that exist around us do so regardless of what we call them or how we interpret them. It is worth postulating that listening with the body is a very direct way of illustrating the idea of the world as experienced by a subject. By using this as a foundation, it is useful to extend this argument to hearing. In Chapter 1, I spoke very briefly about the evolution of the ear and how it functions. In the next section I will look at this sensory mechanism in far greater detail and even though I have established that it is not the only way in which we sense the vibratory environment, it is unique in its sensory process, turning environmental oscillations into what is eventually perceived as sound.

## *The Auditory System*

What is most readily call the ear is actually only the external ear, pinna or auricle, the cartilaginous and connective tissue that is unique in shape to every person. Even though it is unique in shape, there are shared anatomical features that function in particular ways to channel sound waves inward toward the auditory canal. (Siegel & Sapru 2011: 294) The outermost fold at the top of the ear is called the helix and the second ridge that runs parallel to it is called the antihelix. There is a depression that forms at the top of the antihelix, called the triangular fossa, and another semi-circular depression that creates a cup shape around the auditory canal, called the concha. The small protuberance that flaps slightly over the opening of the ear is called the tragus, from the Greek *tragos* meaning goat because of the hairs that grow from it (Moore et al. 2010: 966). The bottom fleshy protuberance is called the lobule. This basic and shared anatomy of the pinna forms what can be described as a series of concentric shapes. (Csillag 2005: 2)

Although most mammals have the ability to move their pinna in order to orientate them towards sound sources, humans are unable to. This is not to say that our pinna do not still function in this way, only in our case there is a tendency to orientate our heads in the direction of the sound source. Putting aside the notion of binaural hearing, which I will look at in detail later, the fact that our pinna channel sound in particular ways and that human beings have two of them that are almost mirror images of each other, is a mechanism for sound source localisation. Brown and May summarise a series of experiments with microphones and artificial pinna that illustrate this point. When sounds were presented to a listener with earphones, the listener located them as coming from inside their heads. To try to establish the importance of the pinna for locating sounds, the experimenter set up two microphones 17.5 cm apart and placed them in artificial pinna. The participants then listened to the sounds with headphones and were able to locate the sounds that were recorded using artificial pinna. When the artificial pinna were removed, the localisation of the sounds was once more inaccurate. (Brown & May 2005: 125) This shows the level of sensitivity of the auricle in channelling sound in sophisticated ways that aid sound source localisation. Even when the sounds recorded with the artificial pinna were replayed to the listener with headphones, the localisation of these sounds was still surprisingly accurate. Thus, the shape of the pinna increases the loudness of the sound that eventually reaches the ear by about 5 dB and also encodes the sounds with directional information (Everest 2001: 43) based on so-called spectral cues. (Young 2007: 431)

The pinna channel oscillations in the air towards the "external acoustic pore" (Csillag, A. 2005: 2), which opens into a cavity called the external auditory meatus. In adults the meatus is between 2 and 3cm long and follows a gentle S-shape. It is lined with ceruminous and sebaceous glands. The former secretes a waxy substance called cerumen (earwax) that prevents potential damage from moisture or foreign materials that enter the canal. (Csillag 2005: 2) The latter secretes an oily substance called sebum that lubricates the hair follicles in the canal. The shape of the auditory meatus and the fact that it is effectively a hollow resonant chamber effectively amplifies particular frequencies (Young 2007: 430) and is also the starting point for the impedance matching that takes place in the middle ear. (Hudde 2005: 58)

The medial end of this tunnel-like cavity is fitted with a thin, even and semi-transparent membrane about 1cm in diameter called the tympanic membrane, or what is commonly refer to as the eardrum. It does not face the cavity perpendicularly but is inclined at an angle of about 50 degrees. (Csillag 2005: 3) This membrane is what separates the external ear from the middle ear and is composed of a thin layer of skin that faces outward and a mucous membrane that faces inward. Viewed from the external meatus, the tympanic membrane is slightly concave and resembles a "mini satellite" (Moore et al. 2010: 967) that moves in response to vibrations in the air.

The inward facing side of the tympanic membrane is attached to a small cartilaginous outgrowth called the manubrium that extends from the first of the three auditory ossicles. During fetal development, these are our very first bones and are fully developed at birth and extremely dense. (Moore et al. 2010: 970) The *malleus*, Latin for hammer, has its handle embedded in the tympanic membrane, and thus moves with the membrane. Its head is attached to the second bone, the *incus* – Latin for anvil. The *incus* has a 'body' and two 'limbs', a long one and a short one. The body is connected to and articulates with the head of the *malleus*. The short limb is connected with a ligament to the bony wall of the tympanic cavity and the long limb runs parallel to the handle of the *malleus*. The end of the long limb connects to the third bone called the stapes – Latin for stirrup. The stapes has a 'head', two 'limbs' and a 'base'. Its head connects to and articulates with the long arm of the *incus*. Its two arms form a wishbone-like formation that connects to either side of its base, which fits directly over the oval window and is attached to it with a ligament. (Moore et al. 2010: 971-972)

The tympanic cavity itself is lined with mucous, is air-filled and connected to the nasopharynx by the pharyngotympanic tube. The tube helps to equalise the air pressure inside the cavity that might push against the tympanic membrane or oval window The contractions of the set of small muscles, called the tensor-tympani, that connect the ossicles to the walls of the tympanic cavity help to restrict the movement of the ossicles and thus to prevent any damage that might be caused by loud noises. Together the components of the middle ear function much like a transducer, which converts oscillations in the air into oscillations in the fluid of the inner ear. Without this amplification system, only about 3% of the vibrations in the air would translate into vibrations in the inner ear. (Siegel & Sapru 2011: 294)

This process of translation mentioned above is called impedance matching. Impedance, or *Z*, is the amount of resistance that a medium presents to the energy that travels through it. In this case, I am concerned with air coming from the outer and middle ear and the fluid that fills the inner ear, where air is a low-impedance medium (low pressure) and the fluid of the inner ear is a high-impedance medium (high pressure). (Young 2007: 432) To illustrate this, sound waves in air will reflect off the surface of water and underwater sound waves will reflect off this boundary too. The function of the outer and middle ear is to translate the sound waves in the air across this ordinarily reflective surface by impedance matching.

In simplified terms, the middle ear performs this translation because the size of the diameter of the tympanic membrane is larger than that of the round window and also because of the finely tuned motion of the auditory ossicles. In engineering terms, ossicles are similar to one large piston that drives one lever that then drives another, that then drives another that is attached to a smaller piston. The area of the tympanic membrane is approximately 80 millimetres squared, and the area of the oval window approximately 3 millimetres squared, which means that the force is decreased 27-fold. The lever action of the auditory ossicles also causes a ratio of decreased motion across the chain of between 1.3:1 to 3.1:1. This means that for every 1.3 times the tympanic membrane moves, the oval window moves only once. (Everest 2001: 46)

With almost unimaginable accuracy, this biomechanical impedance-matching system turns oscillations in the air into oscillations in the inner ear fluid on the other side of the oval window. This clear fluid, or perilymph, is a sodium chloride solution that contains a high concentration of positively charged sodium ions and a low concentration of positively charged potassium ions. (Siegel & Sapru 2011: 294) It fills the bony labyrinth of three semi-circular canals that make up the vestibular system as well as the tiny shell-like structure called the cochlea. For our purpose of discussing hearing, I will overlook the semi-circular canals and focus our attention on the cochlea.

If the middle ear is the translator of vibratory information across the air-fluid boundary, the cochlea is the transducer, turning those vibrations into electrical signals and, furthermore, performing sophisticated frequency analysis on those signals. It truly resembles a snail shell with approximately three and a half turns and is obviously wider in diameter at its base and decreasing in diameter towards its apex. A cross section of an unwound cochlea shows it is divided into three fluid filled chambers or scalae that all run along its coil, each separated by specialised membranous tissue. The topmost chamber is called the scala vestibuli. It is separated from the middle chamber by Reissner's membrane. The middle chamber is called the scala media and it is separated from the bottommost chamber by the basilar membrane. The bottom chamber is called the scala tympani. Whereas the scala vestibuli contains the above-mentioned perilymph, which is high in sodium and low in potassium, the scala media contains endolymph, which is low in sodium and high in potassium and calcium. (Young 2007: 434)

The organ of Corti is located in the scala media, sits on top of the basilar membrane and is the actual sensory mechanism responsible for the transduction of mechanical motion into electrical signals. It consists of supporting cells and hair cells that protrude from its surface. There are two different types of hair cells, inner hair cells and outer hair cells, both of which contain both afferent and efferent nerve fibres. A membrane called the tectorial membrane forms a canopy-like structure over the organ of Corti, just above the hair cells. Towards the base of the cochlea, the hair cells are shorter and become longer towards its apex. Of these hair cells, the stereocilia are the most numerous and the kinoculia less so. Similarly, the nerve fibres associated with the inner hair cells, or type one nerve fibres, are also far more abundant than the hair cells associated with the outer hair cells, or type 2 nerve fibres. (Csillag 2005: 12) When a mechanical vibration enters the cochlea, it causes the basilar membrane to vibrate. The vibrating portion of the basilar membrane responds to the frequency of the sound. High frequency sounds will make the basilar membrane vibrate towards the base of the cochlea and low frequency sounds will make the basilar membrane vibrate towards the apex of the cochlea. (Siegel & Sapru 2011: 294) Furthermore, the basilar membrane is three times wider at its apex than at its base and 100 times stiffer at its base than at its apex. As a consequence of this structural specificity, in 1960 Georg von Békésy proposed a place theory of hearing, according to which a specific frequency is located at a specific place along the basilar membrane. (Goldstein 2010: 273)

The upward displacement of the basilar membrane causes a lateral displacement of the hair cells. The hair cells themselves are essentially ancient mechanoreceptors, similar in structure to those of the agnathans mentioned in Chapter 1. (Csillag 2005: 12) When they are stimulated, the stimulus results in an influx of positively charged potassium ions from the perilymph across the membrane of the hair cells. The cell then becomes depolarised, causing voltage gated calcium channels (channels along the cell membrane that open in response to electronic charge) along the cell membrane to open, which causes the positively charged calcium ions in the perilymph to enter into the cell. As a result of the increase in the overall charge of the cell, similar to what was observed in the case of touch, the cell causes the release of a neurotransmitter which, in this case, is probably glutamate. The glutamate triggers an action potential in the peripheral end of the bipolar afferent nerve fibres located at the base of the hair cells, which are called spiral ganglia. (Siegel & Sapru 2011: 298) I have already mentioned that the location at which the basilar membrane vibrates is determined by the frequency of the sound. The magnitude of the lateral displacement of the hair cells in relation to a particular frequency will trigger more frequent action potentials, and this is determined by loudness and frequency.

The action potential originating at the synapse of the cochlear hair cells eventually terminates in the auditory cortex of the brain. Before it gets there, it travels along the auditory pathway which is much like a train line with numerous stations or subcortical structures along the way. Subcortical structures are basically neural structures that precede the auditory cortex. In brief, the signal travels along the cochlear nerve to the dorsal and ventral cochlear nuclei and are arranged tonotopically, which means that the signals that carry information of high frequency travel to the dorsal cochlear nuclei, while those that carry information of low frequency travel to the ventral cochlear nuclei. (Csillag 2005: 73) These then travel to the olivary nucleus in the brainstem and branch out to the inferior colliculus and the medial geniculate nucleus. It is from the medial geniculate nucleus that the signal finally travels to the auditory receiving area in the primary auditory cortex. (Goldstein 2010: 280) Lastly, at an early subcortical processing, the messages that travel from the left ear and the right ear intersect and it is only when they reach the superior olivary nuclei that there is evidence for the process of sound localisation taking place. (Goldstein 2010: 280)

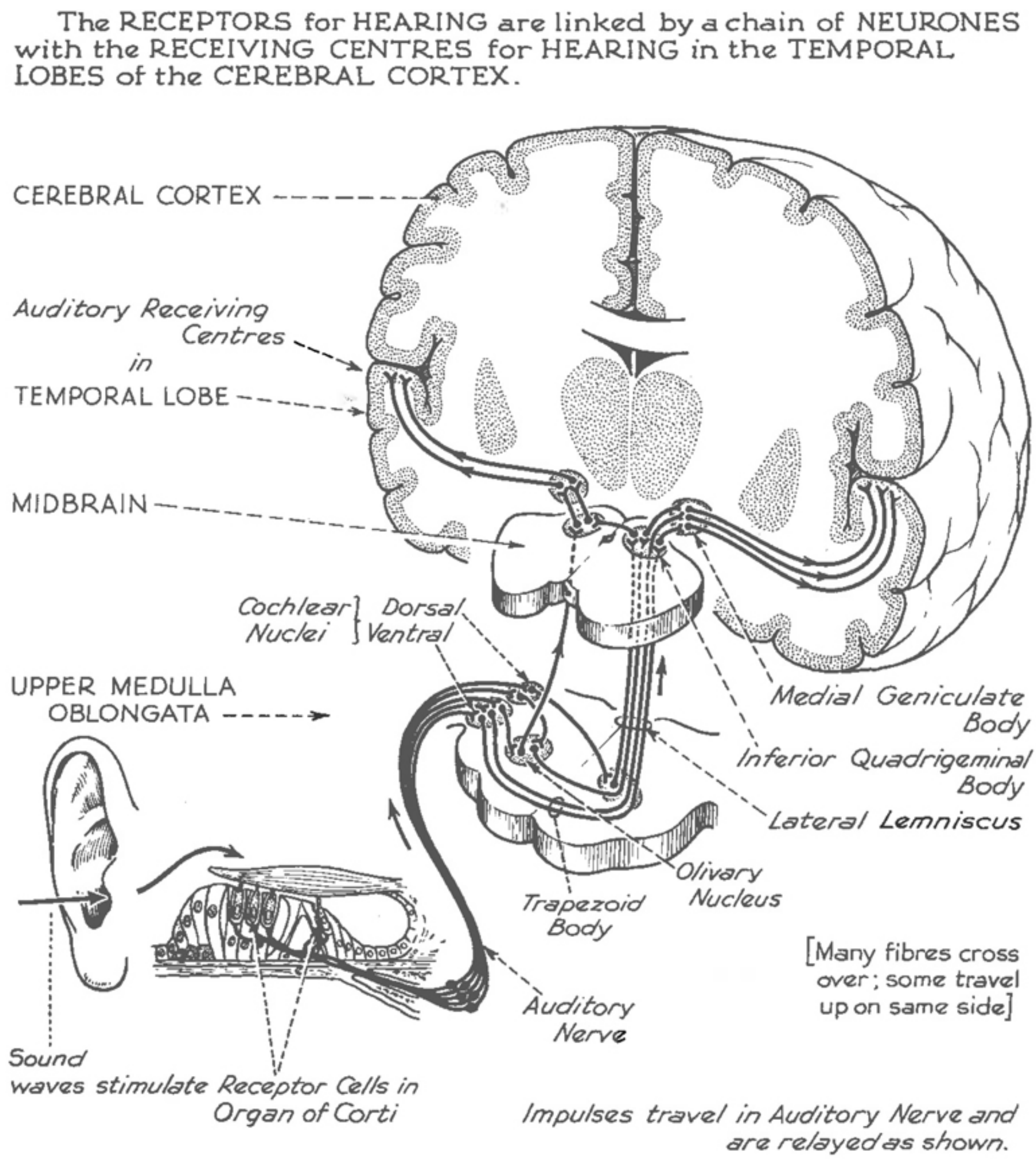



**FIGURE 9: McNaught, A.B. & Callander, R. *Auditory Pathways to the Brain.* (1983)**

Figure 9 illustrates the auditory pathways to the brain. In summary, matter vibrates. These vibrations can be experienced by a subject. The subject in this case is a human being and human hearing is remarkably sensitive. However, many of these vibrations go unnoticed, an issue I discuss in more detail in Chapter 5. The set of vibrations that are experienced are not necessarily only sensed by the ears. Those that are audible fall within a finite range of amplitude and frequency. The mechanical vibrations in the air are translated into mechanical vibration in the perilymph and eventually get translated into electrochemical signals. The electrochemical signals reach the auditory cortex and eventually the frontal lobe and other parts of the brain. It is here and only here that vibration in the air can be called 'sound'. Although there are exceptions, the majority of sounds reach us through the air. In the next section we will establish a number of key points about the various properties of air and how it ultimately affects how human beings hear.

## The Atmosphere: Properties of the Medium

The medium through which sound is heard is the atmosphere. It consists of various gassy layers that reach approximately 90 kilometres into the sky from sea level. Although these layers are collectively referred to as the atmosphere, the layer that is our chief concern is the troposphere or the first 10 kilometres of the earth's atmosphere. This consists of a mixture of gasses, the vast majority of which is nitrogen (78%) and oxygen (20.94%), with argon (0.93%) and minute percentages of other gasses, as well as tiny solid and liquid particles, making up the rest. (Fleagle & Businger 1980: 28-29) Some forces such as wind, vibration and gravity can act on a given system of air and how these pushing and pulling forces act, depends on a number of variables.

In this study, the system that I will eventually be referring to, the city of Johannesburg is an open system. Forces exert themselves on the system from outside of its delineations and it, too, exerts an opposing force beyond the confines of the same relative delineations. It is for this purpose that the discussion below will speak of a system on the assumption that it is open.

The weight of a system of air depends on the amount of substance in the system, or its mass, and the level of resistance to movement or inertia, as well as the amount of gravitational pull on the system. As a result of these combined factors, the higher up in the atmosphere I travel, the less a system of air will weigh; the lower I go, the more it will weigh. (Spellman 2009: 59).

To make the idea of weight measurable, reference to the density of air is made, which is the mass of a given cubic measure of air. The higher the altitude, the less dense the air will be and the lower the altitude, the denser it will be. The amount of weight exerted by the gravitational pull of the earth creates a certain amount of pressure on a given system of air and as a result, the lower the altitude, the higher the air pressure and the higher the altitude, the less the air pressure. The pressure of air will fluctuate in relation to temperature because the kinetic energy in the system increases or decreases in relation to the amount of added or subtracted heat. The pressure in a system of air will decrease when heated and increase when cooled. Consequently, warm air will be less dense than cool air. This would ordinarily mean that with an increase in altitude, there would be a decrease in air pressure. However, a warmer system of air will be less dense than a colder one because the molecules of cold air are packed more tightly together than the molecules of warm air. This causes the cooler air to fall in altitude and the warmer air to rise. Furthermore, the particle matter in the air scatters much of the sun's radiation so that only about 40% of the sun's radiation reaches the surface of the earth and is converted into heat (Spellman 2009: 146). This heat, radiating from the surface of the earth, will be reabsorbed into the atmosphere and will make the surface of the earth warmer at low altitudes and cooler at high altitudes. Finally, the sun remains directly overhead for longer periods of the day at the equator than at the north or south poles and the amount of heat transference is therefore greater, causing an increase in temperature. When all of these factors combine, the result is that, even though hot air rises, there will be a decrease in temperature with an increase in altitude, which is called the lapse rate. (Spellman 2009: 79-81). The average lapse rate of the troposphere means that for every 1-kilometre of increased altitude, there will be a 6.5 degrees Celsius decrease in temperature. (Ackerman & Knox 2006: 73)

Furthermore, air pressure also determines the relative humidity of a given system of air and as a result, less dense air is capable of containing more molecules of water vapour than a denser system. A system of air with a higher temperature will therefore have more room to hold water vapour than a system with a lower temperature. (Spellman 2009: 60-62) The final factor is wind. As an external force acting upon a given system of air, wind is interwoven with temperature, pressure, density and humidity. How these forces fluctuate from place to place, oscillate between day and night and through seasonal changes, forms the properties through which the behaviour of vibrations are determined.

First, it is important to understand how these variables influence the behaviour of atmospheric vibrations; thereafter, I will unpack how this unfolds in our immediate environment.

## *The Rule of Frequency*

The manner in which vibrations in the air behave depends on their frequency, the temperature, pressure and humidity of the air and, of course, the wind. I will stipulate some primary rules and thereafter discuss how they affect the behaviour of atmospheric vibration. Although frequency is not a property of our medium, it is important to bear in mind the first rule: that low frequency sounds tend to travel further through air than high frequency sounds. (Stevens 2013: 5) This is because more energy is lost at high frequencies than at low ones. This phenomenon is called attenuation and explains why elephants can communicate over long distances using infrasonic sound (Stevens 2013: 5). On the other end of the spectrum, bats use high frequency sounds for echolocation because high frequency sounds attenuate rapidly, giving them an 'image' of their environment for only a fraction of a second, much like a stop-motion animation. (Eklöff & Rydell 2017: 21) It must be noted that the frequency of the sound does not influence its speed as the speed of sound only changes when the properties of the medium change. The next three rules all pertain to the properties of the medium.

## *The Rule of Temperature*

The second rule pertains to temperature in that vibrations travel faster through hot air than through cold air. (Rossing 2007: 11) In general, the speed of sound will increase by 0.6 metres per second for every increase of 1 degree Celsius. The speed of sound at 0 degrees Celsius is 331.5 metres per second (Boyce 2014: 24) because the molecules of cold air are more sluggish. The transference of kinetic energy between warm air molecules happens more readily than the transference of kinetic energy between cool air molecules. Earlier, I stated that the closer to the surface of the ground one is, the warmer it will be for a number of reasons. Given this condition, if I were to project a pulse in a longitudinal direction, parallel to the ground, the lower portion of the wave will travel faster through the air than the upper portion. This will cause the wave to refract in an upward direction. (Attenborough 2007: 131)

## *The Rule of Altitude*

Fluctuations in air pressure, it turns out, do not influence the speed of sound in air; however, it is important to consider that air is essentially a gas. What is relevant is the nature of the wave itself as a series of compressions and rarefactions in a medium. The important issue here is the bulk modulus of air and how resistant it is to compressibility and rarefaction. (Tohyama 2011: 90-92) As I have mentioned, sound travels more quickly in hot air than cold air. There is a variation in the speed of a wave in relation to a change in altitude, but this is because there is a change in temperature and not because there is a change in air pressure. Thus, the third rule states that a wave travels more slowly at higher altitudes and more quickly at lower altitude because the temperature fluctuates. At the moment I will set aside the effects that temperature have on wind and how this influences the motion of air particles, and deal with them shortly.

## *The Rule of Humidity*

The fourth rule is that the speed of sound in air will increase with an increase in the humidity of the air. (Boyce 2014: 24) Even though there is no change in the elasticity of the air as a result of a change in humidity, it does influence the density and therefore the mass of a system of air. When water vapour is added to the air mixture, the air becomes less dense and as a result sound waves will travel more quickly through the air when it is more humid. It is important to take into account our earlier discussion about temperature and humidity as warmer air has a greater tendency to hold water than cold air. Thus, when thinking about an increase in humidity, keep in mind that it is correlated to temperature. Below, Boyce tabulates the speed of sound in relation to temperature and humidity: (Boyce 2014: 24)

| | Relative Humidity □ | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| °C □ | 0 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
| 0 | 331.5 | 331.5 | 331.5 | 331.6 | 331.6 | 331.6 | 331.6 | 331.7 | 331.7 | 331.7 | 331.8 |
| 10 | 337.5 | 337.5 | 337.6 | 337.7 | 337.7 | 337.8 | 337.9 | 337.9 | 338.0 | 338.1 | 338.1 |
| 20 | 343.4 | 343.5 | 343.6 | 343.7 | 343.9 | 344.0 | 344.1 | 344.3 | 344.4 | 344.5 | 344.6 |
| 30 | 349.2 | 349.4 | 349.6 | 349.9 | 350.1 | 350.3 | 350.6 | 350.8 | 351.0 | 351.3 | 351.5 |

It is immediately evident that there is a significant change in the speed of sound with an increase in temperature and to a much lesser extent, an increase in the speed of sound with an increase in humidity. Notably, the increments at which the speed of sound increases with an increase in humidity become greater with an increase in temperature.

### *The Rule of Wind*

Our final rule quite simply is that wind either increases or decreases the speed of sound. (Attenborough 2007: 131) As opposed to the intermolecular transference of kinetic energy in a wave-like motion, wind is the actual movement of air molecules on a macroscopic scale from one point to another. Up to this point I have been referring to wind as the movement of air, but it is important to make the distinction between wind and air currents. Wind is the horizontal movement of air and air currents are the vertical movement of air. Wind and air currents are mutually dependent and together result in the constant motion of bodies of air. It is important to be familiar with the basic terminology when speaking about wind and the different types of winds. When speaking about wind, it is always described from its direction of origin, that is, a wind blowing from the north to the south is a northerly wind. When wind encounters an object or obstacle, the side that faces the oncoming wind is called the windward side and the opposing side the leeward side. A specific geographical area would usually have a prevailing wind. (Gabler et al. 2007: 121-122)

## *Air Currents*

The first factor that sets air in motion is the sun. As I mentioned earlier. the sun remains directly overhead for longer periods of time the closer one is to the equator, which means that both the air molecules and the surface of the earth will be warmer. As a result, there is a global motion of heat energy moving away from the equator towards the poles. (Spellman 2009: 134) The gravitational force will cause denser air to move downward and less dense air to move upward and is also the cause of variations in air pressure as a consequence of a change in altitude. (Spellman 2009: 134) Variations in temperature, pressure and density give rise to corresponding gradients along which air moves in an attempt to reach a state of equilibrium. Changes in temperature create changes in pressure and air will move along a pressure gradient, from a high-pressure area to a low-pressure one. The vertical and horizontal motion of air along these gradients, particularly within the troposphere, creates a circular movement as the warm air rises, cools down and falls; and as high-pressure systems replace low pressure systems.

The ocean cannot be overlooked when attempting to come to a complete understanding of air currents on land. The starting point is in the distribution of heat. The ocean carries 40% of the heat generated at the equator towards the poles. (Spellman 2009: 178) This is largely an attribute of the ocean conveyor belt or more specifically the global thermohaline circulation. (Steidler et al. 2001: 18) A major driving force of ocean currents is the wind but as this happens, there is an exchange of heat and humidity. The surface of the ocean retains heat more readily than the surface of the earth and because the air temperature above the surface of the water is lower than that of the surface of the water, the heat is transferred to the water from the air. The rate at which this happens is dependent on the temperature of the ocean current in question in relation to the second law of thermodynamics, which states that heat is transferred from a hot system to a cold system in order to reach thermal equilibrium. Differences in the way that the surface of the earth and the surface of the ocean absorb, or release heat also causes a diurnal pattern of air movement. Typically, during the day, the high pressure, warm air will flow inland and at night, the low pressure, cool air will flow back towards the ocean. (Gabler et al. 2007: 123)

Now that some of the primary forces that set air into motion have been established, it is important to account for a second set of forces that are also at work: the rotation of the earth and the contact of bodies of air with the surface of the earth. The earth rotates from west to east and is wider along the equator than it is at the poles, which means that it spins faster at the equator than it does at the poles. As a result, when air travels northwards from the equator it will deflect to the right. The opposite is true for air moving southward from the equator – it will deflect to the left. (Spellman 2009: 138)

This is also the reason why hurricanes in the northern hemisphere rotate in a counter clockwise direction but in a clockwise direction in the southern hemisphere. It is important to take account of the high and low-pressure belts that encircle the globe as well as, on a lesser scale, the pressure systems that exist within these belts and their change from season to season. Nevertheless, general observations about prevailing winds on a global scale can be made. In this respect, there are six wind belts. From the North Pole, air flows in a general southeasterly direction (a northwest wind) and from the South Pole in a northeasterly direction (a southeast wind). The next two winds, the subtropical winds in both the northern and southern hemispheres, flow in a manner that opposes the polar easterlies. Wind thus flows from the Tropic of Cancer in a northwesterly direction and in the south, it flows from the tropic of Capricorn in a southwesterly direction. The final set of winds are the two trade winds that flow towards the equator from the subtropical highs: the northeasterly trade wind and the southeasterly trade wind. (Gabler et al. 2007: 130) There will be an opposing terrestrial frictional force that acts on the moving bodies of air and because the earth is rotating faster at the equator than at the poles, this force will be greater at the equator than at the poles. (Spellman 2009: 137)

The relationship between the surface of the earth and the behaviour of bodies of air leads us to our next discussion. Up until this point I have been speaking about the macroscopic motion of air in relation to a somewhat idealised environment and I also spoke rather broadly about the surface of the earth, mostly in relation to temperature. I will now look at the composition of the earth's surface and the objects that populate it and see how these factors influence the behaviour of travelling waves in the air.

## *The Surface of the Earth*

The degree to which the ground influences how waves travel above it, are reflected or absorbed and how it causes wave attenuation and interference, depends on what it is made of. On a large scale, what is being measured is the acoustic hardness or the acoustic softness of the ground in relation to high frequencies or low frequency waves. A surface is acoustically hard or soft depending on the porosity of the surface. Whereas a flat concrete or tarred surface is generally said to be acoustically hard because it is not very porous, a surface of soil or snow is less compact, more porous and therefore said to be acoustically soft. (Attenborough 2007: 120) The relationship between these factors will cause either constructive interference or destructive interference depending on the frequency of the wave. Whereas the broad wavelength of low frequency waves is less likely to penetrate the pores of acoustically soft surfaces, the shorter wavelength of high frequency sounds is more likely to do so. (Attenborough 2007: 120) As a consequence, acoustically soft surfaces will cause constructive interference: both low and high frequency waves will reflect off the surface and could even cause resonance in the wave travelling above the surface. Acoustically hard surfaces will result in destructive interference: the waves will attenuate downward as a result of the resistance to absorption into the pores.

The most immediate idea that comes to mind when thinking about the surface or the ground is that of soil, which is not often associated with less built-up areas. Soil is acoustically soft but the degree to which it is porous depends on a number of factors which influence how sound will travel along its surface. The porosity of soil is proportional to its hydrological percentage: the more waterlogged the soil, the less air it will contain and the drier the soil, the less water it will contain. This is measurable and the result is called the air permeability of soil. (Lal & Shukla 2004: 536). Similarly, the opposing forces of soil will make it more or less likely for air to permeate its pores or to hold water, for example. This is called flow resistivity.

The composition of the soil is the primary factor in determining its air permeability. Soil is a mixture of various organic and inorganic solids, liquids and gasses. Generally speaking, the organic and inorganic solids comprise 50%, the gasses 25% and the liquids 25%, with the exact composition being dependent on the compaction of the soil.

(Lal & Shukla 2004: 13). The size of the solid matter in soil, in other words, the particle geometry, will also determine how large the voids between the particles are. Thus, with an increase in the size of the solid particulate matter there will be an overall increase in air permeability as well as how well the soil retains water. Although the literature that deals with the relationship between different soil types and sound is still underdeveloped, a number of provisional claims can be made with reference to what has already been established in relation to air permeability. The higher the soil's air permeability, the more sound it will absorb. This being said, I will look quite broadly at different types of soil and how they would influence the waves in the air above them.

Firstly, when I speak about soil, I am referring to a particular layer of the earth's crust and in this context, it is useful to make a distinction between rocks and soil. There are three different types of rock, namely igneous rock, sedimentary rock and metamorphic rock. Igneous rock was once in a liquid state and then solidified as it reached the earth's surface; sedimentary rock was formed by weathering that, over time, formed layer upon layer of sediments that then became compacted; and metamorphic rock is a combination of igneous and sedimentary rock that has undergone both chemical and physical processes. (Smith & Smith 1988: 2-3) Physical and chemical forces act on these rocks in different ways and break the original rock, or parent rock, into smaller and smaller pieces that eventually become soil.

There are three different modes of soil formation. The first is transported soil, where wind and water transport soil particles, the heavier particles obviously being less likely to be moved. The second is residual soil that is formed as a result of chemical weathering. The third is organic soil, formed as the result of decomposition of plant and animal matter. In general, soils are classified according to their particle size as well as inter-particle forces. Whereas less cohesive soils are grainier and their individual grains less likely to bind together, cohesive soils are flakier, and particles will be more likely to bind together. (Smith & Smith 1988: 4) It is thus safe to conclude that cohesionless soil will be less likely to retain water close to its surface and will have higher air permeability. It would therefore be acoustically softer than cohesive soils that will retain water close to its surface and will also have low air permeability. The texture of the soil also influences how the air above it behaves. A rough surface will likely cause more destructive interference of the waves that propagate in the air above it than a smooth surface. A smooth surface will most likely cause a constructive interference of the propagating wave in the air above it, as the wave gets reflected.

Thus far, I have generally treated the surface as homogenous and have proposed a broad set of guidelines for how the surface is likely to impact waves that propagate above it. However, the surface is in actuality not flat and consists of a variety of topographical features that shape the fingerprint of the landscape; moreover, it is populated by objects that could be large or small, few or many, stationary or in motion. In this sense, the topographical fingerprint of the landscape creates a unique ecosystem that determines the nature of the objects that populate the landscape. These range from the orographic effects that mountains have on wind, humidity, rainfall and water drainage to the type of vegetation and animal life that exists as a result of the climatic conditions that the particular form of land provides. Thus, the relationship between topography and vegetation mould the acoustics of the landscape in a way that is unique to each biome. In the discussion that follows, I will look at some of the world's terrestrial ecosystems and make inferences about the acoustic properties of each. I will go into more detail about concepts such as absorption and reflection at a later stage.

## Three Different Biomes

### *The Desert*

The most sparsely populated ecosystem as far as vegetation is concerned is the desert and its most notable attributes are its lack of water, its extreme temperatures and its vast barren landscapes. Deserts usually have an annual rainfall of less than 25cm and because the sand is very porous, there is little very little evaporation and therefore the air has a very low level of humidity. (Begon et al. 2006: 24) The temperatures of deserts are not necessarily always hot, such as in the Sahara; they can also be extremely cold at night or be generally cold, as in the case of the Gobi Desert. Furthermore, not all deserts have very little vegetation and the surface of warm deserts especially can become quite densely populated by plants. (Chaplin et al. 2011: 59) The wind is a major factor in the topographical form that the desert takes. Firstly, the leeward side of the world's mountain ranges are usually drier than the windward side and as a result, deserts will form downwind from the leeward side. (Chaplin et al. 2011: 38) Secondly, the various ways in which the wind carries grains of sand will in all likelihood eventually form the major topographical feature of the desert, namely the dunes. The intimate relationship between wind and the formation and anatomy of dunes has been well documented by Lancaster. (Lancaster 1995: 9) For the immediate purpose, it is important to consider the acoustical implications of the desert environment.

In deserts that have very little to no vegetation, the surface will be generally be aerodynamically smooth and very few trees and shrubs will scatter a propagating wave. The surface of the desert is most likely to be extremely hot and this will cause a wave to attenuate upward from its source. The propagating wave will travel more slowly because of the lack of humidity and will also travel more slowly at night, when the temperature falls. The grains of sand are likely to be large and, depending on the air permeability of the surface, this will cause upper frequency sounds to be absorbed. The form of the desert is predominantly shaped by the motion of air and there is a fluidity to the way in which, at least in theory, waves will travel along these shapes. Lastly, the sparseness of the desert, the smoothness of its surface and the vast open spaces would mean that soft sounds are likely to propagate over long distances.

## *The Grassland*

Grasslands tend to occur in the interior of continents, have low winter temperatures, high summer temperatures and, for the most part, erratic patterns of precipitation. (Chaplin et al. 2011: 52) There are two different types of grassland, temperate and tropical, and both display a high density of grass and shrubbery and a low density of trees. Carpeted by grass, the surface of the grassland is almost spongy and absorbs surface water quite readily. The soil type is classified as mollisols to describe its crumbly texture. (Woodward 2008: 19) Water will return to the atmosphere in the form of evaporation and transpiration and the mild temperatures of temperate grasslands generally result in an average level of humidity. Whereas tropical grasslands form over much longer periods of time, have a higher annual rainfall and soil that is reddish and rich in iron, temperate grasslands generally formed after the last ice age (between 6000 and 8000 years ago) and are characterised by their semi-arid climate. (Woodward 2008: 8)

The carpet of grass typical of grassland is essentially a homogenous, highly porous, spongy layer. The grass will thus cause resistance to a propagating wave and cause it to attenuate slightly downward. The blades of grass themselves will cause the wave to reflect off them and scatter. As temperate climates have mild temperatures and an average relative humidity, the speed of sound does not change to a notable extent, although the cold dry winters will cause sound to travel more slowly in comparison to the rainy warm summers. Lastly, grasslands generally form in the rain shadow region on the leeward side of mountains and warm, dry winds blow over their surfaces. (Woodward 2008: 16) The warmth of this wind will accelerate the momentum of a propagating wave that travels in the same direction.

## *The Tropical Rainforest*

At the other end of the spectrum is the tropical rainforest. I will speak specifically about broad-leafed evergreen rainforests. They are consistently located between the Tropic of Cancer and the Tropic of Capricorn where the average temperature (20-30 degrees Celsius) and average precipitation are high, and the rainfall is consistent throughout the year. (Holzman 2008: 1) I noted earlier that, for a number of reasons, this region will be subjected to northeasterly and southeasterly trade winds, and these air masses transport a high volume of water to the rainforests. A leafy canopy cloaking the rainforest absorbs the majority of the heat from the sun during the day, keeping the lower forest cool and the surface of the ground moist. During the day, the heat is gradually transferred through the canopy to the lower forest, but when night falls, this heat is retained below the canopy. The lower forest will therefore be warm at night and the canopy will be cool. (Holzman 2008: 21) Even though the soils of rainforests are varied, they fall into a general category of laterites, which are soft, porous and clay-like in texture. (Allaby 2006: 37) The surface temperature of the soil does not fluctuate much at all and the clay-like soil, even though it is low in nutrients, holds water very well. (Holzman 2008: 27) Only a small fraction of the light that the rainforest receives ever reaches its floor and consequently the surface has little vegetation and is covered by dead leaves and other debris.

The ground effect of the nonporous moist soil, covered by a layer of porous leaves, litter and debris with little vegetation, is that the hard and moist substrate has a high flow resistivity and is likely to absorb every little sound; it would typically cause a constructive impedance as a propagating wave reflects off it. However, the leaf litter and debris will counteract this because it has a low flow resistivity and thus will absorb a propagating wave, causing resistance and a gradual attenuation of the wave downward. The canopy itself has a low flow resistivity and will also scatter a propagating wave, and the tree trunks themselves will cause reverberant scattering. (Attenborough et al. 2007: 320) The high temperature and humidity will increase the speed of a propagating wave. The number of factors involved in the absorption of sound is likely to mean that mid to high frequency sounds will travel quickly but not for long distances.

In conclusion, I have looked quite broadly at the acoustics fingerprints of different environments and, for the sake of brevity, excluded many of the world's biomes. Nevertheless, I have arrived at a general understanding of how the different ground surfaces and their flow resistivity impact on the acoustics of the landscape. I have explained how the temperature, humidity, wind and topography of these environments influence the properties of the air and consequently how sound will behave as a result of changes in these variables. The form and texture of vegetation will absorb and scatter a propagating wave in ways that create a special acoustic image that is completely different from one biome to the next. All these factors link together in an intimate set of relationships that coalesce into the acoustic identity of each space.

## The Behaviour of Sound Waves

Earlier, I discussed some of the physical qualities of a propagating wave. At this stage it is necessary to go into greater detail about how these waves behave in air. What is immediately noticeable is that sounds are louder at their source and get softer further away from their source. There are a number of reasons for the gradual dissipation of a wave as it propagates. Here, I will look specifically at the loss of intensity and the loss due to heat. For much of the discussion of waves, they have been imagined having a rectilinear shape. But waves in air do not travel in a straight line; they radiate in all directions from their source. Therefore, when explaining the loss of intensity, it is useful to describe the wave as spherical. When a wave travels from its source, it travels in all directions and the sphere gets larger. Recalling an earlier discussion, sound intensity is the power per area, and because the area of the sphere is larger the further away from the source it travels, the intensity of the sound will inevitably decrease. The energy of the wave is essentially mechanical, moving air particles backwards and forwards. As the particles oscillate, the mechanical energy is converted into heat energy. Heat energy is non-conservative and cannot be converted back into mechanical energy; it simply returns to the environment. (Katz 2017: 263) This heat loss is exponential to the distance that the wave travels and therefore the oscillations of the air particles will become smaller and smaller until eventually they cause no molecular disturbances at all.

Even though it has been helpful to imagine an ideal environment in explaining the fundamental behaviour of a propagating wave, the environment is never empty. It has a surface in the form of the ground and is populated by objects of varying sizes, shapes and textures. In the following section, I will look at how wave propagation happens in the context of factors such as absorption, reflection, reverberation, scattering, interference, refraction and diffraction.

Depending on the properties of a surface and the frequency of the propagating wave, when a wave encounters a surface it can be transmitted, reflected or absorbed. It is important to emphasise that the type of wave that I am describing is a longitudinal wave that propagates in a perpendicular direction from its source. When this wave encounters a surface, the angle at which it encounters the surface is called its angle of incident. Its angle of reflection will be related to its angle of incident, much like a billiard ball. The surfaces that populate our environment are static and have bearing on the way that waves in the atmosphere interact with them. Some of the acoustic energy of the wave can be transmitted from the medium of air into another medium such as water or wood if the frequency and the medium are in phase, for example, and some of the acoustic energy will be absorbed by the medium which the wave encounters. No surface is completely reflective or completely absorbent and the two poles of the absorption coefficient, 0 for a surface that is completely reflective and 1 for a surface that is completely absorptive, are therefore theoretical in nature. (Cowan 2007: 390) When a wave gets absorbed, the kinetic energy is transformed into heat energy. Air itself has an absorption coefficient.

The amount of absorption is dependent on the frequency of the wave, with high frequency waves more readily absorbed than low frequency ones. High frequency waves are more likely to be absorbed by porous or fibrous materials, and low frequency waves are more likely to be absorbed if the thickness or density of the material is increased. (Karczub & Norton 2003: 316)

Sound reflection and echoes are essentially the same phenomenon except that the echo by definition requires the wave to be transmitted and returned to the sender. An explanation of the terrestrial bioacoustical application will help us understand this in more detail. Echolocation, SONAR (sound navigation and ranging) and biosonar are different names for the same ability to use acoustic reflection for the purpose of creating an acoustic image of the environment. Many animals use echolocation, but the best known of these are bats, or more specifically microcheroptera. The principle is fairly straightforward mathematically. Beginning with the speed of sound in the medium $V_s$ in relation to two elements of time, the initial time $V_i$ and the final time $V_f$. It is possible to measure the time difference between transmission and reception $\Delta_t$=$V_f$-$V_i$. Then, relating the amount of time that it took for the wave to travel from the transmitter through a given medium where at some point it is reflected off an object and returns to the point of transmission, it is possible to locate the object in space or length $L$. Quite simply, the final expression is thus:

$$L = \frac{V_s \Delta_t}{2}$$

Of course, this is an oversimplification, but it is essentially what happens automatically and on a continuous basis in the case of bats. In addition, bats ensonify their environments, in other words, flood their environment with acoustic signals that give them highly detailed information about the spatial location of objects. As a result, they can perceive objects in three dimensions as an auditory scene. (Madsen & Surlykke 2014: 257-259)

When a continuous wave reflects off a surface two waves result: the original wave and the reflected one. Two waves, whether caused by reflection or by two different sound sources, interact with each other in ways that can cause either constructive or destructive interference. Constructive interference occurs when waves are in phase and destructive interference when they are out of phase. (Berg & Stork 2005: 41) Returning to our earlier depiction of a simple sinusoidal wave will allow us to explain this phenomenon in simpler terms. In the ideal case of constructive interference, the two wavelengths both begin with a positive value, the distance between the equilibrium position and the peaks is equal, the distance between the valleys and the equilibrium position is equal and the wavelengths are also the same, or in phase. When one wavelength is superimposed on top of another, the peaks and the valleys combine and amplitude will increase twofold; in other words, the wave will be twice as loud. In the ideal case of destructive interference, the waves are as similar as described above but one wave begins with a positive value and the other with a negative value. When one wave is superimposed on top of another, the full extent of the first wave's peak will align with the full extent of the valley of the other, and both are cancelled completely. This also occurs with three-dimensional spherical waves that are in or out of phase but instead of amplifying or cancelling each other in a simple fashion, a geometric pattern of radiating lines is formed where the points at which the waves amplify each other are called nodal lines and the points at which they cancel each other out antinodal lines. (Berg & Stork 2005: 43)

The next logical addition to our established understanding of interference is a phenomenon called beat frequency. This is what occurs when waves that overlap have different frequencies. At some points, their peaks will overlap and cause constructive interference and at other points, the peaks will overlap with the valleys and cause destructive interference. Initially the waves will increase each other exponentially until they reach their highest peak; thereafter they will decrease each other exponentially to the point where they cancel each other out. The resulting waveform creates a rhythmic pulsation or warbling within the compressions and rarefactions of the air molecules. (Berg & Stork 2005: 50)

The case of reflections as demonstrated by echoes is to a large extent special. The more common case is reverberation, which occurs when a propagating wave reflects many times over and as a result, the acoustic energy is prolonged over a greater length of time, known as the reverberant time, than if it were not reflected and directly propagated. It has already been established that acoustic energy is dampened and dissipates at what is called the rate of decay. The continual reflections indicative of reverberation means that the rate of decay is extended as a function of the space in which the wave propagates.

Howard & Angus describe reverberation by using the analogy of a leaky bucket. A tap filling a bucket at a specific rate represents acoustic input, and the bucket represents the form of the space in which the acoustic energy is contained. The rate at which the water leaks out of the bucket represents the rate of decay and the rate at which the water level falls represents the reverberation time. (Howard & Angus 2009: 291) If the number of reflections increase, the reverberation time will increase. In so-called 'dead spaces' the reverberation time is short and in 'live spaces' it is long. It is also worth noting that reverberation is frequency dependent in that low frequency sounds are less likely to be absorbed and more likely to be reflected. They will therefore have a slower rate of decay and a longer reverberation time than high frequency sounds, which are more likely to be absorbed, have a shorter decay time and are more likely to have short reverberation times. The relationship between low frequency, long reverberation times and high frequency, short reverberation times is called the warmth or brilliance of a space. Whereas in warm spaces, the low frequency reverberation times exceed the high frequency reverberation times, in brilliant spaces the high frequency reverberation times exceed the low frequency reverberation times. (Berg & Stork 2005: 219-220)

In a given terrestrial environment oscillations in the air molecules are determined by the properties of the air. As the waves propagate, they encounter objects that vary in their physical composition and form. When they encounter these objects, they are transmitted, reflected or absorbed. The waves that are reflected combine with the original wave as well as other waves that are reflected, which cause constructive or destructive interference. The cumulative constructive interference causes reverberation. The result of how the space and the objects within it shape reflecting waves is to give the waves texture. (Berg & Stork 2005: 220) When all of these factors coalesce, it is possible to conclude that the formal attributes give the space its acoustic signature and that the behaviour of waves resulting from these factors defines its acoustic identity.

All the objects in our environments have geometric properties of some sort and also physical properties such as density. The geometric and physical properties of an object have modes of acoustic expression that are particular to the object, its natural frequencies. When an object is struck, the immediate effect is that it vibrates at its natural frequency, the frequency at which it will most readily vibrate. (Kirkland 2007: 91) External forces have the ability to act on the object in a way that matches the object's natural frequency. It can be struck repeatedly, for instance, and the rate at which these repeated strikes occur could become equal to the natural frequency of the object. The matching of the frequency of the external force to the natural frequency of the object will increase the amplitude of the natural frequency of the object and cause resonance. (Kirkland 2007: 91)

All of the objects of our environment are tuned to a point along a spectrum of frequencies and when waves propagate through the air, they encounter these objects as well as the range of frequencies inherent to these objects. When this happens, the frequency of the waves in the air could act as an external force and the object can act as a resonator.

This phenomenon was famously illustrated by German physicist Ernst Chladni (1756-1827). Chladni fixed a metal plate horizontally over a vibrator. The vibrator was connected to a signal generator that could be tuned over a spectrum of frequencies. On the surface of the metal plate, Chladni scattered sand and as the metal plate vibrated, the sand would move. Initially, the sand would bounce around on top of the plate in a haphazard way. However, when the vibrator was tuned to very specific frequencies, the sand would form very distinct patterns on the plate. The frequencies that caused the patterns were mathematically identical to the natural frequency of the metal plate. (Chladni 2015: 73-122)

The directional behaviour of a propagating wave in air can be affected by the properties of the air itself. Depending on the variations in these properties the sound can attenuate to varying degrees, causing parts of the same wave to travel more quickly or slowly. The properties of the surfaces of the environment can also have this effect of refraction. Depending on the properties of a particular surface and its absorption coefficient, it will create a degree of resistance to the portion of the wave that travels along it. The portion of the wave that travels at a distance from the surface will not encounter any resistance and will therefore travel more quickly than the portion experiencing resistance. The result is that a wave traveling parallel to a surface that causes resistance will refract and the sound will attenuate downward. (Katz 2017: 506)

The most widespread example in the literature in explaining this phenomenon refers to an ocean wave. When an ocean wave travels ashore the surface of the ocean floor creates resistance and the wave loses momentum as a result. However, the part of the wave that does not encounter resistance from the ocean floor will maintain its momentum and eventually result in what is typically seen as an ocean wave.

I have already discussed how a wave can be reflected off a surface with respect to its angle of incident and its angle of reflection. When a wave encounters an object, its path is interrupted by the object and much of the wave is reflected and an acoustic shadow is cast behind the object. In an environment populated by objects of different shapes and sizes, the wave is reflected in many different directions, to the extent that even though the object obstructs its path, the wave has the potential to reflect into the shadow zone behind the object. This is one of the ways in which a propagating wave is able to travel around objects; the other is by diffraction.

Diffraction is the bending of waves as they move through an opening or around and object into the shadow zone behind the object. (Pierce 2007: 98) There are two basic factors to consider in order to explain diffraction: the wavelength and the size of the object or opening. When a wave propagates in the direction of the object it does so in a series of concentric circles. The distance between the peak of the first circle or the wave front and the peak of the second circle is the wavelength. When the object or opening is equal to the size of the wavelength, true diffraction occurs, and the wave envelops the object or propagates into the entire shadow zone behind the opening. When the object or opening is larger than the wavelength, the amount of diffraction will decrease. (Pierce 2007: 98) An extension of this phenomenon is that longer wavelengths diffract more than shorter wavelengths: as the wavelength increases in length there is a proportional loss of diffracted power. (Berg & Stork 2005: 45)

Imagine pure tone is played and a snapshot in time of the wave it produces is taken. A number of different types of waves and waves in the air are typically emitted in all directions from the source of the disturbance, creating peaks and troughs or compressions and rarefactions in a series of concentric circles. For the purpose of this illustration, imagine that the air is homogenous, which means that the speed of the waves is the same at any point in the medium; and also, isotropic, with the speed the same in all directions in which the wave travels. If a circle is drawn along each point where the waves are at their maximum compression, these lines are the wave front. If points are plotted along the circle and lines are drawn from the position of the disturbance to each point, the lines will give us the direction in which the wave fronts are travelling. The direction at any of these points shows that the wave propagates in a perpendicular direction from each wave front. The point of reception is typically not the entire surface area of the wave front, which is why in many cases we look only at a small section of the sphere and treat it as a rectilinear shape with a plane wave front travelling through it.

A set of fundamental laws forms the foundation for a discussion of the behaviour of mechanical waves in air and are particularly important for the understanding of architectural acoustics, to be discussed in Chapter 5. The first is Huygen's principle, which states that every point on a wave front is a source of secondary wavelets, which in the case of our spherical wave are also spherical wavelets. (Berg & Stork 2005: 31) This is important for the diffraction of waves. The second is the law of superposition, which states that two waves can be present at the same time in one location, one wave being superimposed on the other. (Breazeale & McPherson 2007: 212) This helps us understand constructive and destructive interference. Thirdly, the inverse square law describes the loss of intensity the further away from the source the waves are. In brief, intensity is power per area and the area of a sphere is $4\pi r^2$. Spheres closer to the source of the disturbance have a smaller surface area than those further away, and thus intensity is inversely proportional to the radius of the sphere. (Berg & Stork 2005: 32-33)

In this chapter I have looked at sound and hearing through the lens of classical mechanics and neurobiology. This understanding of the behaviour of sound is contingent on the accurate measurement of mass, distance, time and temperature because it allows for the measurement of motion and elasticity. The chapter focused on sound waves in gasses and particularly air and explained how longitudinal waves in air behave. A detailed account of the biological mechanisms of hearing was given and the route of a sound wave in the air to the auditory cortex was traced. It became evident that the sounds that are audible fall within a narrow range of loudness and frequency. Against the background of these objective circumstances, environmental variables such as temperature, humidity, altitude and wind were described in relation to how they affect the behaviour of sound. This understanding was then applied to three different biomes: the desert, the grassland and the tropical rainforest. Based on this more precise comprehension of the environmental factors that shape sound, as well as the highly complex biological mechanisms that convert waves into perceivable sounds, it is now becoming possible to speak more systematically about sound art and the acoustic environment of Johannesburg.

In what follows I will shift attention from the physical nature of sound and hearing to the experience of sound and the way that sound is apprehended by a subject. This shift is analogous to the difference between hearing as a passive and detached registration of sound to active and engaged ways of listening. (Carter 2004: 43) It will become clear that the process of hearing has become by necessity habitually automised – a phenomenon that is arguably more endemic to the urban environment. Drawing on Viktor Shklovsky's *Art as Technique* (1917), it will be argued that one of the functions of sound art is to remove sound from the field of automated perception of acoustic events by "making it strange" and, in so doing, consciously connecting sound to the perception of the environment and time. To draw on a visual analogy, Jasper John's *Flag* (1954) demonstrates how an image that pervades the eye can become a subject that, through the use of paint, delays the eye. The challenge for sound art is to find ways to make the listener pause and come to terms with the immediacy of their auditory experience. There are numerous methods at the sound artist's disposal that make this possible but in order to develop this point it is important first to look in detail at the auditory experience of time and space.

# CHAPTER 5: SOUND IN THE PERCEPTUAL WORLD

> I am in communication with one being, and one only, a vast individual from which my own experiences are taken, and which persists on the horizon of my life as the distant roar of a great city provides the background to everything we do in it. It is said that sounds or colours belong to the sensory field, because sounds once perceived can be followed only by other sounds, or by silence, which is not an auditory nothingness, but the absence of sounds, and which, therefore, keeps us in contact with the being of sound. If, during the process of reflection, I cease to hear sounds, and then suddenly become receptive to them again, they appear to me to be already there, and I pick up a thread which I had dropped but which is unbroken. The field is a setting that I possess for a certain type of experience, and which, once established, cannot be nullified.
>
> (Merleau-Ponty 1962: 382-383)

In the previous chapter a detailed account of the physical properties of sound was provided in order to gain a more complete understanding of what sound is and how it behaves. However, for these physical vibrations to be called sounds at all, they need to be perceived. Our perception of sound is inseparable from our perception of time and space. Sound is spatially located; it is perceived to come from here or there. Sound also extends itself along a length of time; it is perceived as either lasting for long or short periods of time. In what follows, time and space will be discussed in order to provide an account of sound as it is perceived and experienced.

## Sound and the Perception of Time

In the previous chapter I spoke of time as regular measured intervals. This explanation was sufficient for understanding the measurement of the movement of air particles, the distance which a sound wave travels and the rate at which a sound wave oscillates. However, it did not account for our experience of time or the role of sound in this experience. Therefore, this section aims to discuss the defining characteristics of auditory perception and its relationship the experience of time. Sound waves themselves are not perceived but cause us to perceive sounds. Auditory perceptions do not present all that is audible to us simultaneously; it is selective, and this selectivity is what gives the auditory perception its "distinctiveness and individuality" (Carr 1914: 91)

### *Order and Duration*

Four preliminary factors stand out in our perception of time, namely: change, succession, persistence (Daiton 2013: 390) and simultaneity, all of which are significant to our perception of sound. In brief, sounds change *over* time and this change can be experienced as gradual or sporadic. Sounds are heard *in* time as a succession of events in relation to each other, and sounds are experienced as successive events that are either in close temporal succession or distant temporal succession. Time persists in the presence and absence of sound. The sound itself, and the duration between one sound and the next, could both be experienced as either long or short. This is of particular significance to the understanding of attention and perceived duration and will be discussed later. Lastly, sounds can be heard at the same time, with many layers of sound potentially occupying the same moment in time. These four factors point to the fact that our perceptual experience of sound is inextricably bound to our experience of time. There are two essential features of the time-based nature of auditory experience: order and duration.

A physical account of sound would state that sound is comprised of the repetition of one wave pulse after another in rapid succession. However, the ear does not perceive sounds as comprised of discrete units; rather, what is perceived is an unbroken flow that corresponds to the illusory continuity of temporal experience and the sense of the passage of time. Therefore, it is not possible to take a snapshot of a sound; perceptions of sounds are by definition perceptions that unfold over time. The unfolding of sound has a temporal order that flows from the future into the present and towards the past. (Le Poidevin 2007: 98-99) This can be said about single sounds as well as a succession of sounds. A single sound has an onset time, which is perceived first, and as it dissipates and eventually becomes inaudible, a termination time. Successive sounds are also perceived within a temporal order. The sound that is presently audible recedes into the past as it is replaced by another.

The challenge arising from audition and perception as a whole can be posed as a question: if what we perceived is only perceived in the present, then how do we perceive succession at all? This is commonly referred to as the 'phenomenological paradox'. (Deng 2013: 371) To assert that auditory perception only selects the immediate present is inconceivable. Thus, in order to perceive sounds in the current moment, the ear cannot be isolated from the past and the future. Auditory experience requires an awareness of duration. The period of time that is being referred to as 'present' must necessarily contain both elements of the past and of the future and be perceived within the order of temporal experience.

To elucidate this further, the abovementioned example of single sounds, which have an onset time and a termination time, is helpful. Suppose that the onset time is 'one' and the termination time is 'two'. If 'one' is present, 'two' is in the future and if 'two' is present, 'one' is in the past. 'One' proceeds towards 'two' and 'two' refers back to 'one'. Thus, 'two' is partly present in 'one' and 'one' is partly present in 'two'. When we listen to 'one' we are anticipating 'two' and when we are listening to 'two', we are recalling 'one'.

What the examples attempt to illustrate is that the auditory experience of the present is a "foreknowing" as well as a "forefeeling". (Zuckerkandl 1969: 228) In the present, I am listening both backwards and forwards in time. The flow of forefeeling into foreknowing is related to the audible perception of duration. Single sounds themselves have duration – I am aware of when they began and anticipate either their continuation or their ending. (Wessman & Gorman 1977: 39) The same can be said for the intervals between sounds: I am aware of when a sound ended and anticipate either its return or another sound.

## *Auditory Attention and Time*

Having established the essential temporal features of the auditory experience, it is important to expand on this understanding by making mention of the role of attention in our experience of time. The auditory perception of duration is subjectively experienced and can vary in length, and accurate or synchronous estimations of the duration are therefore not always the norm. It is more often the case that the perception of duration is either "protracted" or "compressed" and deviate from the synchronous perception of duration. (Flaherty 1999: 40, 115) Flaherty found that protracted duration (when time seems to elapse more slowly) is an anomaly that occurs as a result of suffering and intense emotions, the experience of violence and danger, waiting and boredom, altered states, concentration and meditation, and shock and novelty. (Flaherty 1999: 43) Temporal compression (when time seems to elapse more quickly) is most often associated with retrospective experiences of duration and is possibly a result of the stimulus complexity of an experience. (Flaherty 1999: 104)

The relationship between the role of attention and the experience of duration is well documented and the arguments are diverse. However, there are two influential arguments:  the cognitive argument and the argument of change. The cognitive argument falls under two categories, prospective judgments of duration and retrospective judgments of duration. Whereas participants are told to attend to duration in prospective experiments, they are asked to reflect on duration in retrospective experiments. The underlying premise of the cognitive argument is that duration cannot be perceived without attending to time. (Phillips 2012: 276) The general implications are that when the ear attends specifically to time, estimations of duration are more accurate than when the ear attends to sonic elements that are not related to time, such as intensity or texture, for example; in this case, estimations of duration are shorter. (Phillips 2012: 279) The inherent postulation is that there must be an internal counter or cognitive clock that is capable of translating experiences of duration into time more or less accurately. Thus, when attending to the length of a sound where there is nothing inherent to the sound that provides temporal cues, attention moves away from the sound itself towards the act of keeping or paying attention to time.

The notion of 'attention to time' is itself questionable because essentially time is not perceptible at all. This leads to the well-documented assertion that it is not time that is being perceived but change. Sounds are perceptions of changes in the environment. This line of reasoning relates the role of attention to the experience of duration by drawing on the old adage: a watched pot never boils. (Phillips 2012: 283) Thus, when listening to a sound that changes frequently, time would seem to elapse quickly and when listening to a sound that changes less frequently, time would seem to elapse more slowly. On the surface, this seems plausible. If more attention is given to the changes in a sound, less is given to the experience of its duration. Conversely, when less attention is allocated to change, more attention can be allocated to the experience of duration.

Whereas the cognitive argument tends to neglect the environmental context and the influence of the content of auditory experience, the argument from change tends to neglect the cognitive context, the expectation of an early or late ending and the emotional state of the subject, all of which bear influence on why certain auditory experiences seem to take longer than others. (Zakay & Block 1996: 144-146) How all of these factors not related to change itself, as well as perceptible change, influence the subjective experience of duration is a question requiring further research. Most likely, the experience is a combination and complex interrelationship of a variety of factors. For example, listening to a sonically cluttered environment could draw attention away from the passage of time and make it seem as if time is elapsing quickly. However, the cluttered environment might also increase our level of anxiety, making it seem as if time is elapsing more slowly. Similarly, listening to a single tone could draw our attention towards the passage of time and make it seem as if time is elapsing more slowly. Clearly, it is a combination of factors that influence the experience of time.

In conclusion, the role of attention in the experience of duration has been researched in terms of cognitive factors as well as factors related to perceptible change. What has been relatively neglected is how a combination of factors might be at play. This is certainly true for auditory perception, where a number of considerations, some of which relate to the sound itself and some not, influence the experience of duration. In light of this, by foregrounding sound, sound art has the ability to divert attention towards or away from time and thus have a direct influence of the perception of duration. The protraction and compression of duration cannot be seen as exclusively the result of the sound itself and environmental factors need to be considered.

In the next section the auditory perception of space is discussed. It provides a close analysis of auditory perception and space. In light of what has been asserted in relation to the auditory perception of time, it will be important to take note of the fact that the auditory perception of space is always a function of time.

## Spatial Orientation

In the previous chapter I established how different environments influence how sounds behave and discussed in some detail how the physiological mechanisms of the human auditory system translate these oscillations into signals for the brain to interpret. It is the aim of this section to establish how the mechanisms of human hearing provide information about states of affairs in the world, with a specific focus on information about the spatial continuum in which we are located. Not only do we locate ourselves in auditory space in a way that is relational, but we are able to perceive the dimensions of this locale as well as the motion of objects within it. The former case, with which I will begin, relates to binaural hearing and the latter to directional hearing and orientation. Once this has been established, I will discuss architectural acoustics within the urban setting, with a specific focus on Johannesburg. It must be emphasised that visual localisation is about twice as accurate as auditory localisation. However, we are unable to locate visual objects through, around or over obstacles but are able to do this with hearing. (Moore 2013: 245) Our hearing has evolved to locate sound sources in ways that are adapted to the ability of sound to traverse the objects and obstacles in our environment.

For the purpose of this study it is sufficient to work with the notion of space as a physical continuum. (Bregman 1990: 73) When we locate a listener within this continuum, it becomes an anthropocentric continuum, i.e. as experienced by a subject. Near and far serve as indicators of our realm of potential action. (Heller 1984: 236-237) An integration between auditory distance, verticality and left and right orientation allow us to sense the auditory scenery of our environment. In what follows I will look at how this occurs, mostly in the context of the free field. The free field, as indicated before, is an uncontrolled environment as opposed to the laboratory. It is subject to sound reflection as opposed to an anechoic chamber (a room designed to absorb all reflections). An argument can be made that the built environment is not a free field in that it has been constructed in ways that deliberately shape acoustic space. However, for the purpose of this study I will assume that it is outside the boundaries of what is typically called a laboratory setting, a sound proof room or an anechoic chamber and is therefore a free field.

Although the literature pertaining to hearing and distance discrimination is underdeveloped, there are three established factors that allow us to accurately judge whether or not a sound is near or far as opposed to loud or soft. These factors do not function in isolation but work actively in shaping the distance-related information from our environment.

The first of these factors relates to intensity. I have already discussed the inverse square law in relation to the loss of sound intensity as a function of distance. In the typical situation, sound is emitted in an omnidirectional manner, much like a sphere. When a sound is heard, the ears sample a small section of the sphere. As a result, the closer we are to the source, the greater the sound intensity. This is different from loudness and softness in the sense that a loud sound will still have a loss in intensity as a function of distance. (Grantham 1995: 325)

Secondly, I have already discussed reverberation and reflection. There is a distinction to be made between the direct signal and the reverberant signal and in judging distance, our hearing is able to use the ratio between the two as another distance cue. This is known as the precedence effect. Briefly, the greater the direct signal in relation to the reverberant signal, the closer the sound. As a result, we are better able to locate the distance of sounds in spaces that are more reverberant than in spaces that are less so. (Grantham 1995: 326-327)

Thirdly, spectral cues are used to perceive distance. High frequency sounds tend to travel shorter distances, while low frequency sounds tend to carry over longer distances. Therefore, when a sound source is closer to the ear, it is likely to have a greater high frequency content than if it were further away. (Grantham 1995: 328) Thus it is possible to conclude that if a sound source is far away, it will have a reduced intensity, its direct signal will be less than its reverberant signal, and that if it is a low frequency sound it will be more dominant than one with a higher frequency. If a sound is closer, however, its intensity will be greater. The direct signal will be stronger in relation to the reverberant signal and high frequency sounds will be more dominant than low frequency sounds.

In the median-plane vertical directional discrimination of sounds, one ear is as good as two as "interaural differences are uniformly zero". (Carlile 1996: 16) It is the torso in the case of low frequencies and the pinna in the case of high frequencies that allow us to determine whether a sound is above us or below us. (Baumgartner et al. 2013: 94) This means that when a sound is the same distance away within the median plane, we are able to locate it in terms of elevation as well as whether or not it is in front of or behind us. The discrimination of sound source elevation as a property of the pinna is largely determined by the complex shape of the pinna. The pinna shapes the sound in particular ways that feed information to the eardrum about its elevation. This is due to constructive and destructive interference which cause "spectral notches" in the sound that enters the outer ear canal. (Lopez-Poveda et al. 2007: 51) The source of the destructive interference is the multiple reflections within the pinna itself. (Kuhn 1987: 15) Furthermore, the way the sound is diffracted, specifically by the helix and as a result of the shape of the pinna, also encodes the waveform that enters the auditory canal with directional information related to its elevation. (Batteau 1967: 167)

The role of the pinna in sound source localisation can be demonstrated by the occlusion of the pinna cavity, leaving the auditory canal exposed. Gardner and Gardner filled the pinna with a putty-like substance and then investigated the ability of the subject to locate sound sources in the median plane. As one can imagine, the sound source localisation was inaccurate when the pinna were occluded. (Gardner & Gardner 1976: 403-406) As I noted earlier, low frequency sounds are less likely to be absorbed so it would make sense that low frequency sounds that are reflected from one's shoulders and torso provide median-plane vertical directional information that is encoded into the sound that travels into the auditory canal. To be more specific, whereas low frequency sound elevation discrimination as a function of the shoulders and torso relates to sounds below 2 kHz, high frequency sound elevation discrimination as a function of the pinna relates to sound over 4 kHz. (Kuhn 1987: 15)

## Sound-Source Localisation

Having discussed proximity and elevation, I now turn to the third and most widely studied facet of our auditory spatial perception: sound localisation or directional hearing. It is often the case that the literature treats these two terms interchangeably, as two ways of defining the same phenomenon. For the purpose of clarity, however, a clear distinction must be made between the two. We will refer to sound localisation as the ability to perceive from which direction a sound is coming, and to discriminate between two different sounds coming from different directions. Directional hearing is more particular and has to do with the ability to focus one's attention on a particular sound source as a consequence of the ability to localise sound. Importantly, sound localisation related to proximity and elevation are monaural, as opposed to binaural localisation, for which two ears are required. Furthermore, whereas two identical sounds arriving at each ear at the same time are diotic, the moment that the sounds are not identical they are dichotic. The essence of sound source localisation and directional hearing is that the sounds are dichotic.

Sound localisation requires two ears and the cues that they receive from the environment are processed by the brain in particular ways that allow us to obtain an accurate sense of the state of affairs in our auditory locale. In thinking about the lateral plane, it is sufficient to imagine the head as a circle with one sound receiver on the left and another on the right, and also to think about the sound that encounters the sphere as a rectilinear longitudinal wave. When a sound travels from the left, for instance, the left receiver will be directly irradiated, and the right receiver will be in the shadow boundary of the sound. As a result of this, the sounds will be dichotic in a number of ways. (Kuhn 1987: 5) The first difference is in time: the directly irradiated receiver will receive a signal before the right receiver does. Keeping in mind that it is the same direct signal, the difference in time between it encountering the left and right receivers already establishes the conditions for the lateral localisation of the sound source. Perhaps this is stating the obvious but the fundamental discrimination that allows us to locate sound is, first and foremost, a result of interaural time difference. It is surprisingly accurate: if a sound is coming from the front and one turns one's head only a few degrees, the interaural time difference changes and so, too, the directional information. The measurable precision of the ability to differentiate between one source and another is called the minimum audible angle. It is most accurate within the frequency range of between 1.5 kHz and 20 kHz and also most accurate when the two sound sources are in front of the head as opposed to on the right- or left-hand side of the head; it is also more accurate when they are on the lateral rather than the vertical plane. When two sounds are within this frequency range and their sources are in front of the head, the minimum audible angle is between one and two degrees, which means that turning one's head towards a sound source does indeed result in a more accurate judgement of the sound source's location in space. (Gelfand 2005: 459-462)

Because low frequency sounds are more likely to refract around objects than high frequency sounds, the accuracy of binaural cues is greater for high frequency sounds than for low frequency sounds. (Moore 2007: 484) The same applies to the difference in sound intensity that reaches one ear before the other: high frequency sounds tend to lose their intensity as a function of distance more readily than low frequency sounds. As a result of a decrease in the likelihood of higher frequency sounds and a fluctuation of intensity cues, higher frequency sounds are more likely to cause a sound shadow on the side of the head that opposes the direction of the oncoming sound. Consequently, our ability to locate sounds using time difference cues is optimal over 1.5 kHz and our ability to locate sounds using intensity cues is optimal over the range of 2-3 kHz. (Moore 2007: 484-485) The location of higher frequency sounds depends more on a difference in intensity between one ear and the other, whereas lower frequency sound source localisation is more dependent on time difference. (Berg & Stork 2005: 162)

The three factors that contribute to sound source localisation – proximity, elevation and localisation on the lateral plane – work together to help us locate sound sources. It has been useful to use single sounds for the purpose of explaining the mechanisms that are at work when locating sounds, but in reality, sounds arrive from all directions and the objects that emit these sounds are not always stationary. The sounds of our environment arrive as a stratified complex and yet we are able to peel away the layers and compartmentalise the ingredients in meaningful ways. In the next section I will explain how auditory scene analysis and attention operate for the purpose of making sense of auditory space.

If two sounds that emanate from the same direction have the same loudness and pitch it is still possible to distinguish one from the other because of a variety of attributes that the sounds possess. It is safe to assume that the sounds in our environment do not consist of simple sinusoidal tones but rather of complex tones of varying degrees.

Therefore, the first attribute that allows us to distinguish one sound from another is timbre. Timbre is the textural quality of a sound and is most easily understood using musical instruments. If a piano plays a note it sounds different from a violin playing the same note. This can also be likened to vowel sounds. Even if vowels are articulated at the same pitch and loudness, we are able to distinguish one from the other because of their timbre differing in spectral quality. (Moore 2013: 285) This being said, complex tones are produced by objects. I made the case in Chapter 4 that all objects have a fundamental frequency. This means that even if the same piano plays different notes it will always emit the same fundamental frequency, which further aids our ability to discriminate between one sound object and another. If two sounds are identical in that they arise from the same direction and are equal in pitch and volume it is very unlikely that their onset time will be identical. This is especially true for the sounds in the free field. As a result, we are able to distinguish one sound from the other based on the asynchrony of the sounds as they reach us.

A defining factor in sound transmission is that sound reaches our ears over a period of time. Within this context there are two perceptual mechanisms that allow us to discriminate between sounds: coherence, where perceptual fusion occurs; and segregation, where perceptual fission occurs. (Moore 2013: 300) We are more likely to attribute a sound to a single source if there is continuity in its frequency, loudness and pattern. Such predictability will cause us to ascribe the sound to a single source. But when these continuities are disrupted to a noticeable degree it will cause us to ascribe the sound to two or more different sources. (Moore 2013: 300-301) Even though this is a rather brief account, it leads us to an important set of principles that explain how we perceptually organise our auditory space as the foundation of how we locate and orientate ourselves within this space.

I have accounted for some of the primary ways in which we perceptually differentiate one sound source from another. From this can be extracted five general principles that govern our perceptual ability to ascribe sounds to their sources within the theoretical framework of Gestalt psychology.

The first principle is similarity. Sounds that are similar in location, pitch, loudness and timbre are perceptually grouped together and separated from those that have different sets of similarities. Thus, I can recognise that the sound of birds is to my immediate right, the sound of traffic to my immediate left, and to my distant left I hear school children playing during break time. There are perhaps five different birds chirping, a seemingly endless stream of vehicles of different shapes and sizes and maybe three hundred children playing on the field. Each bird, car and scholar are different, but I am able to generalise and group the sounds in terms of proximity, timbre, loudness and pitch. (Moore 2013: 300-301)

The second principle is continuation. When there is continuity and regularity within the formal qualities of a sound, we tend to ascribe it to a single source, whereas we are likely to ascribe a sudden disruption within this continuity to a second source. This can happen on an immediate scale or broader scale. In the immediate sense, the stream of traffic consists of mostly cars and there is nothing particularly different between them. Even though I am aware of individual differences I group them by similarity and therefore also by continuity. Because of this continuity I ascribe the sound of cars to a singular sound source and call it the sound of traffic. When, however, there is a sudden discontinuity, say a motorcycle suddenly passing by, a new sound source is activated. (Moore 2013: 305) On a broader scale, if we know that between Monday and Friday the sound of traffic will be at its height in the morning and afternoon, the disruption of this pattern contributes to the assumption that it must be either Saturday, Sunday or perhaps a public holiday.

The third principle is common fate. If sounds start together and end together, we tend to ascribe them to a common source. (Moore 2013: 306) More specifically, if sounds start together, end together as well as change in the same way relative to pitch and amplitude they are grouped together. The case of an orchestra is most commonly used to illustrate this. The string section starts and stops more or less at the same time in a way that differs from the woodwind section. Therefore, we group the string instruments together and perceptually ascribe their sound to the same orchestral section.

The fourth principle is that of disjoint allocation or belonging. This means that there is a singular limit to the number of sources that a sound can be ascribed to. Once we have perceptually allocated a sound to a source it cannot then be ascribed to another source. (Moore 2013: 306-307) When one car after the next becomes the sound of traffic, it is not possible then for the sound of a bird chirping to be allocated to the sound of traffic. The sound of the bird does not belong and will thus be allocated to a new source.

The fifth and final principle is closure, which leads us to the discussion of attention and masking that follows below. For the time being it is sufficient to say that when we are attending to one sound, we are not attending to another. Closure is basically the filling in of blanks. When we are attending to one sound that has continuity and another sound interrupts it briefly, the principle of closure allows us to bridge the interruption in a way that suggests that for the brief moment that we did not hear the sound, it was unchanging. The most cited example is from speech. When one person says to another "The cat sat _____ the mat", the natural perceptual inclination of the other person is to assume that the blank space is occupied by the word "on". This is the same for the stream of traffic to my immediate right. Say that I am listening to it and my phone suddenly rings and I take the call. The natural perceptual inclination would be to assume that the stream of traffic continued even in the absence of me attending to it, and even though it is possible that the stream was interrupted by something while I was on the phone. (Moore 2013: 308-309)

## Auditory Attention and Space

Within the context of coherence and segregation and the principles that function in ascribing sound sources, our sonic space can be defined as numerous sets of multidimensional, layered streams of sounds. The auditory system almost reflexively does the work of compartmentalising these sounds into their relevant streams. It would seem that it would take a conscious effort to separate them, in the same way that perhaps we see a person and think of them as a whole. It takes a conscious and deliberate effort to see one leg adjacent to the other, connected to a torso with one left arm and one right and a head on top. Nevertheless, this reflexive compartmentalisation makes the auditory manageable, to say the least. It is also the case that even though we are aware of the existence of all of the streams, we are generally only capable of focusing our attention on one of the streams at a time. The Gestalt psychologists call this the figure-ground relationship of attention where the stream that we are focusing our hearing on is the figure and all of the other streams, whether there are a few or many of them, are grouped together as the ground. (Moore 2013: 309 & Koffka 1936: 200-204)

Interestingly, there is some evidence that reinforces the relevance of the figure-ground relationship in how we locate sound, and to which sounds we pay attention. In brief, we are more capable of locating unexpected sounds than we are of locating sounds that are expected and would therefore already be compartmentalised into a stream. (Styles 2006: 126) This means that, in the context of auditory attention, there is no strict border between the figure and the ground, and it would be more productive to think of the relationship between the two as a gradient. The background could easily rupture into the foreground, and we are more capable of pinpointing the site of this rupturing within space when it does so unexpectedly.

This is often likened to the ocular-centric spotlight metaphor where there is a centre of visual attention and a periphery. (Posner 1980: 19-21) There might be something within the periphery of one's vision that 'catches' your eye and on which you then focus your visual attention. As tempting as it is to apply this same metaphor to audition, it does not wholly suffice. We do not direct our hearing by some mechanical means towards a particular point; even though we might turn our heads towards a sound source this is a very rudimentary reaction. The auditory periphery is also far more spacious: we can direct it in all directions and at great distances. The focal points of auditory attention are also more flexible, considering that we are able to tune into a particular source or the entirety of a stream. The interrelatedness between the centre of attention and the periphery is also more dynamic. A sound can enter our auditory focal point from any direction, and we can shift our attention towards it regardless of the obstacles that prevent us from seeing the source. Finally, whereas visual and auditory awareness and attention is more closely linked to that which is immediate and familiar, auditory awareness and attention is, in the opinion of this study, more open to distance and the unfamiliar.

The fact of the matter is that a cross-modal model of attention is more accurate. Hearing is accompanied by vision and in most cases, vision will take precedence over hearing, hence the ventriloquist effect. It is more likely that we will locate the sound of the ventriloquist's voice in the dummy because we see its mouth moving than in the ventriloquist's mouth, which appears not to move. This is also evident when one is listening to the radio in a car. The speakers are most likely in both front doors but when we look at the radio located in the central console of the car, it seems as if the sound emanates from the radio face. There are many more examples, but all of this is really a result of the fact that spatial attention is neither visual nor auditory but dependent on both and that most often, the visual takes precedence. The same applies to the other senses. Consequently, there is a field of investigation that aims to prove that there is a mechanism of attention that functions independently of the senses even though it is dependent on them. (Styles 2006: 143-146)

## Sound and the Perception of Motion

Sound is a product of motion. Low frequency sounds oscillate slowly, and high frequency sounds oscillate more rapidly. When I speak of the slowness or rapidity of oscillatory motion, it is within the context of motion in a spatiotemporal framework that makes two presuppositions based on perception. The first is that "there can be no motion without time, and there can be no time without motion". (Buckley 1971: 43) This is evident in popular fiction in that the freezing of time is always accompanied by the freezing of motion. The second presupposition relates to the directionality of time or the arrow of time: that there is a past, present and future and that events in the past are causally linked to the present, with events in the future causally linked to the present and so forth. (Nahin 1993: 125) Of course, neither of the two presuppositions is necessarily true but in the context of sound and particularly in relation to perception of motion, it would be unrealistic to dispute them.

I have largely spoken about sound as being emitted by stationary sources and arriving at a stationary hearing entity. In reality, sound sources are not always still: the cars that travel along the road on my right-hand side are moving from the top of the road towards the bottom, and the birds on my left-hand side move around and might choose to fly away. We, too, are not still. Our heads pivot around on our necks; we may choose to stand up and walk to another room. We are aware that our auditory space is a place of moving soundmaking objects and that we have the ability to locate these moving objects by the sounds they make. It is now possible to apply what has already been discussed.

When a sound source travels from the left to the right, it will encounter our left ear before our right ear, and it will gradually fade along the binaural spectrum to a point where it will reach our right ear. If the amount of time that it took for the sound to travel between the two points is short, we perceive it to be travelling quickly, and vice versa. This is also a product of proximity. If a sound source is nearby, we perceive it to be moving quickly. For example, a vehicle travelling on the road to my right will only make itself audible for four seconds at the most, but an airplane flying overhead might be audible for much longer. Were it not for the fact that we know that the airplane travels much faster than the car, our perceptual auditory presuppositions would have us thinking that the opposite were true. Furthermore, the spectral qualities of the sound of a moving object changes over time – such is the case with the Doppler effect.

The perception of motion is essentially the perception of change (and thus a function of time) in the conditions that underlie our ability to locate sounds. If a sound is approaching us there is an increase in intensity and if it is moving away from us, there is a decrease in intensity. The same can be said for sounds travelling from the left to right and sounds that increase or decrease in elevation. There also is a change in the spatial relationships between different sound sources. Within the variety of our attentional streams we relate the motion of sound sources to the background streams of sound. To be more specific, we are able to make acute auditory discriminations of the change in distance between one sound source and another. Similar to the minimum audible angle discussed earlier is the minimum audible movement angle. This is the ability to perceive the motion of one sound source in relation to another. A sound source need only change by a factor of two to four degrees before we notice that its spatial relation to another sound source has altered. (Grantham 1995: 329)

There are two predominant views about the perceptual auditory judgment of motion. The first suggests that there is a dedicated motion-sensitive mechanism within the auditory system that enables the perception of moving sound sources. The second suggests that we take auditory snapshots of our environment and because there is a variation in the distribution of sound sources, we infer motion as a result of the change. (Grantham 1995: 329) There is also the opinion that both perceptual mechanisms are at work but there is still little evidence for the existence of either. The fact is that we are able to perceive motion by auditory means, whether it is the motion of one sound source or the motion of many sound sources in relation to one another.

Finally, when we locate ourselves spatially in relation to the sounds that present themselves to us from all directions, our ears are not the end point of the sounds: they will continue beyond our location in space. A sound is projected from one place and travels to another place where it will eventually dissipate. As a sound travels along an uninterrupted chain of places our awareness of its motion means that the perception of space and time have a complimentary relationship. (Winckel 1967: 77)

What this section has attempted to show is how the ear functions in providing an impression of sound source localisation as well as direction, both of which would not be possible without a connection to a temporal awareness of sound. When locating a sound source, the ear must make a determination, between the beginning of the sound and the end of the sound, about the spatial relation between these two points, which helps us to locate the source. This requires an amount of time. Directional hearing and sound source localisation are only possible because a sound falls on one ear earlier than the other.

Much of our discussion of sound source localisation and directional hearing has still been in a hypothetical free field environment. Earlier I mentioned that this free field environment should, at least superficially, include the built environment. In the section that follows I will discuss architectural acoustics, the acoustic identity of the built environment and how it influences our relation to our own auditory space within the city. It is the broader aim of this discussion to show that how we locate ourselves within auditory space in the city is architecturally orchestrated. It will also be important to briefly discuss phenomena such as reverberation and spaciousness in relation to the perception of time.

## Architectural Acoustics of Indoor Spaces

> Space, in fact, is liberty of movement. That is its value to us, and as such it enters our physical consciousness.
>
> (Scott 1914: 227)

The relationship between architectural ideas of inside and outside, private and public space, is imposed on the way that the behaviour of sound is structured, particularly in the context of urban space. The liveness of a space, or its reverberation time, is directly related to the impression of spaciousness. Live space is more reverberant than dead space, for example. An empty room with reflective walls will be livelier than if objects that absorb sound are placed inside the same room. Before the objects are placed in the room, the space will have more reverberant characteristics (live) than when absorptive objects are placed in it (dead) – longer reverberation times suggest that a space is bigger and shorter reverberation times suggest that it is a smaller space.

The biggest area of contestation in terms of sound and urban space is how to design for noise control. The uninterrupted eye that travels beyond the volume of the space can give the impression that the space is larger than it is. However, being able to hear beyond the spatial delineations of a room is somehow deemed problematic. In many cases, it is considered favourable to have a view of the outside but not be able to hear it. It is also most often the case that the design of indoor spaces receives much more attention than the question how buildings affect outdoor spaces or what effect the façade has on the acoustics of public space. The emphasis tends to be on soft private acoustic space, and outdoor public space remains acoustically untreated. As a corollary of noise control, the primary focus in the design of rooms is on speech intelligibility: we want to be able to optimise our ability to communicate effectively. Not surprisingly, interior space is primarily modelled in relation to the anthropometric dimensions of the body and the frequency range of the human voice (between 100 – 600 Hz). (Binggeli 2003: 397)

### *"Good Hearing"*

It is beyond the scope of this paper to provide a detailed account of the history of architectural acoustics; this is well documented in Fredrick V. Hunt's book *Origins in Acoustics: The Science of Sound from Antiquity to the Age of Newton* (1978). However, the modern tradition of architectural acoustics focused on sound insulation, noise control and speech intelligibility within the context of "good listening", begins with the work of C. Sabine:

> In order that hearing may be good in any auditorium, it is necessary that the sound should be sufficiently loud; that the simultaneous components of a complex sound should maintain their proper relative intensities; and that the successive sounds in a rapid articulation, either of speech or music, should be clear and distinct, free from each other and from extraneous noises. These three are necessary, as they are entirely sufficient for good hearing.
>
> (Sabine, quoted in Sabine 1932: 11)

Sabine's legacy is still evident today in several ways. Firstly, he approached the acoustic treatment of spaces as only pertinent to auditoria, spaces that are purposefully and exclusively designed for listening, in opposition to spaces that are not designed for listening. The fact of the matter, however, is that all spaces are potentially auditoria. When one moves from one space to the next there is no predetermined expectation to stop or start listening. Listening is continuous irrespective of environmental conditions and it is especially indifferent to whether a space has been conceived with listening in mind. Nevertheless, the idealism around providing the environmental conditions for good listening persists. Secondly, the relative intensities of sound presuppose a condition of balance and an orderly acoustic behaviour of sound in space. This is clearly not how sound behaves in nature and not how human hearing is designed to work. But for Sabine, imposing conditions of equilibrium on listening was a prerequisite to good listening. Lastly, there is a separation of sounds that are deemed important from those that are deemed noisy. This politicises sound and imposes a hierarchical relation between those sounds that are preferred and those that are not. Good listening is deemed to exist only in an architectural acoustic void detached from all contextual contingencies. This is the most far-reaching implication of the conditions imposed by Sabine. We generally live in an acoustic milieu that privileges some sounds over others. Only in rare cases, such as in the work of John Cage, do sounds become democratised in stark opposition to Sabine's acoustics of isolation. Insofar as "good listening" is concerned, we still live with the legacy that certain sounds are preferable to others that should be clear and distinct.

Architectural space designs the resonant properties of acoustic space. It would seem as if the ideal spaces for good listening would be suited to the space formed from an architecture rooted in good proportions. In making this suggestion it is difficult not to evoke the Pythagorean tradition of harmonics and geometry, the former related to how numbers exist in time and the latter to how they exist in space. The common denominator between the two is the golden section. (Olsen 2006: 38) Over time, this relationship between harmonics and geometry has manifested itself in the proportions of buildings in an almost cult-like fashion. The underlying proportions found in nature would provide Vitruvian man with the 'proper' proportions for architecture, with the aim of designing a harmonious society. Superimposing mathematical proportion onto subjective experience is an appeal to self-evident truth. This becomes even more evident in the disjointed and uneasy relationship between classical architectural harmony and geometric acoustics. Harmony and proportion as envisioned by the architect's eye seldom translate into spaces for good listening.

### *Room Acoustics*

In order to arrive at a more complete understanding of architectural acoustics, an analysis of room acoustics is needed. Rooms have a variety of different uses and users. What emerges is a relationship between the objective and quantifiable acoustic characteristics of rooms and the subjective qualities of and interpretations of room acoustics. The first deals with the properties of sound waves in an enclosure within the context of its intended use, the second with how the acoustic properties of enclosures are experienced by one or more subjects.

Rooms are typically cuboid or shoebox-shaped and rarely exist in isolation from other rooms. One room is connected to another in a modular fashion by doorways, corridors or common spaces such as courtyards. For the most part, rooms are intended to be private spaces. What will become evident in this section is how there is an uneasy acoustic relationship between the inside and the outside and, therefore, notions of the private and the public. To reinforce the notion of being inside a room as a private experience, architects often take measures to contain the sounds we make in the room as well as to protect the space from environmental sounds. This is particularly true in the urban environment and Johannesburg is no exception. Effectively the room becomes a space where the urban soundscape comes into focus by virtue of the tendency to try and exclude it. The room in this sense is a vantage point where the sound of the urban environment is amplified and in focus. By attempting to make rooms quieter, the sounds of the environment become more noticeable, as Idhe explains:

> One gestures "away from" sound "towards" silence. And the more effective this gesture-direction becomes, the more one realises silence, the more radical the intrusions of formally unobtrusive auditory disturbances become.
>
> (Idhe 2007: 222)

The irony is that the ideal indoor environment has many of the acoustic qualities that outdoor environments have. This relates primarily to the contrast between direct and reverberant sound. The aim is to reduce the amount of reverberation and thus protect the amount of direct sound the listener receives from the sound source. In an outdoor environment or free field, there is a relative lack of reflective surfaces, and also a relative lack of reverberation, which is a natural consequence of the dissipation of sound over distance. If the sound has nothing to reflect off, it will not interfere with the line of transmission between the sound source and the listener; the sound becomes unbounded. Indoor spaces, by contrast, are for the most part cuboid in nature, with six reflective surfaces. In order to mimic the low levels of reverberation that are characteristic of the outdoor free field, acoustic design often makes use of sound absorption materials. Instead of sound behaving as it naturally would, dissipating as a result of distance, sound absorption suppresses the reverberant field. This relates to the size of the room and to what extent the materials the room is made of are reflective. (Cowan 2007: 390)

In this context, it is now possible to apply what was discussed about sound reflection in Chapter 4. However, here I look at how sound reflects off a wall. Suppose a wall of infinite extent and a sound propagating towards it at a 90-degree angle: the sound that returns will do so at the same angle. I mentioned the billiard ball example. It has already been established that the angle of reflection at which the sound bounces of the wall is proportional to the angle of incidence. The fact is that enclosed spaces have multiple reflective surfaces, which can cause a variety of angles of incidence that cause many angles of reflection. If the room is typically constructed from rigid materials with smooth surfaces, sounds tend to reflect many times over. Sound travels spherically in a cuboid room constructed with rigid reflective surfaces. As a result, the acoustics of spaces is most commonly reverse engineered aimed at reducing the number of reflections by taking into account the geometry of the space, the reverberation time and the diffraction and dispersion of sound. (Blauert 2005: 14)

In sharp contrast, there are spaces that are designed to intentionally work with the natural spherical behaviour of sound, with its tendency to reflect and dissipate as a result of distance. Whispering galleries such as those in St. Paul's Cathedral in London or Grand Central Station in New York are good examples. A curved wall or domed ceiling allows the sound to reflect off a curved surface. Each reflection creates constructive interference with the direct sound and, as a result, the sound will dissipate more slowly and travel further. In this sense, the wall becomes a sonic conduit. (Kutruff 2009: 121)

It is clear that when speaking about room acoustics, reverberation time is the defining acoustic feature. This is likely to be a consequence of the fact that it is easily measurable and does not depend on the location of a listener. Data on the reverberation time of different kinds of room is widely available. (Kutruff 2009: 229-230) A distinction must, however, be made between reverberation and spaciousness. Whereas reverberation is objective, measurable, and dependent on the dimensions of a space as well as the absorption and reverberation coefficient of the surfaces in a particular space, spaciousness is subjective.

### *Spaciousness*

The sensation of auditory space occurs on the lateral plane. (Kutruff 2009: 240) It is the reflections that we hear on the lateral plane that give us the impression that a space is either large or small. This begins with the notion that the initial reverberations that result from a space are not noticeable before 50 milliseconds after the onset of the direct sound source. In theory, we are unable to distinguish the direct sound source from the early reverberation sounds and perceive them as one sound. (Damaske 2008: vii) The phenomenon where the direct sound masks the initial reverberations is known as forward masking. (Gade 2007: 305) This is immediately followed by a slow decay or late reverberations. The relationship between these three factors – the first wave front, the early reflections and the later reflections – work together to give us the impression of spaciousness, or what Damask calls diffuseness. (Damaske 2008: 66) This is clearly correlated to interaural time difference and again inseparable from the perception of time. Thus, the same auditory mechanism that allows us to locate sound on the horizontal plane functions, in relation to diffuseness, to give us the sensation of space. In a small room the sound will have less diffuseness than in a large room. According to Damaske, irrespective of the reverberation time in a small or large room, the sense of diffuseness will result in the perception of it being small or large. This is related to the apparent source width. The amount of time it takes for a sound to reflect on the horizontal plane creates the impression of spaciousness: narrow time lapses give us the impression that a space is small and longer time lapses give us the impression that a space is large. (Gade 2007: 309) Diffuseness points to the spaciousness of the room as a product of how the sound permeates the room.

Damaske's ideas are relatively dated and his articulation of the phenomenon is obscure, to say the least. Thankfully, the ideas have permeated recent literature in clearer terms. Here a distinction is made between the uses of the term in physics, as opposed to psychoacoustics. In physics, diffuse means that the sound energy in a room is isotropic and homogenous and that all the angles of incidence of the sound wave have equal probability. In psychoacoustics, however, which is where the Damaskian notion comes from, it pertains to the "non-locatedness" of the sound-in-space experience, the sound being located throughout the space. (Kleiner & Tichy 2014: 262) This expression of diffuseness, however, in both physics and psychoacoustics, points to the spaciousness of the sound as a product of the room size.

Finally, listener envelopment is the sense that the listener is inside and surrounded by the reverberant sound field. A listener will feel more enveloped by the reverberant field in spaces with shorter reverberation times, in which the surfaces are reflective. When a listener feels less enveloped by the reverberant sound field, it will give them the impression that the space is large. (Gade 2007: 309)

Thus far, I have provided sufficient detail about how sound behaves in rooms and have noted that there are three branches of investigation that help us understand how we experience the room on a spatial level: physical acoustics, geometric acoustics and psychoacoustics. It is evident that the major acoustic behaviour of sound relates to the threshold between the inside and the outside of the room. Sound insulation aims to contain the sound inside the room by absorption and prevent the sound from the outside to enter the room. In the next section I will look at the soundscape of Johannesburg and how sound in the urban environment finds its acoustic identity through the way it is experienced.

## The Soundscape of Johannesburg

This chapter has thus far provided a detailed analysis the perceptual experience of sound. In order to extend on this understanding, the following section will begin by drawing on the soundscape theory of Schafer and Krause and thereafter focus on the soundscape of Johannesburg. The primary aim of this section is to provide further clarity about the soundscape of Johannesburg. In the absence of precise research, I have chosen to take a phenomenological approach based on personal experience, observation and reflection.

Whether the sound artist records or plays sounds, they inevitably engage into an auditory dialogue with the soundscape and it is important to be aware of the central themes of this conversation. With reference to Johannesburg, there are three central themes that I wish to propose. The first is the soundscape and history, which describes how the soundscape of Johannesburg has changed over time as well as how characteristics of what we hear presently reveal aspects of the past. The second is the soundscape and spatial separation, which shows that, even though the soundscape of Johannesburg can be distributed into different zones, each with its own acoustic identity, these zones frequently overlap. The third is the soundscape and the perception of noise, which aims to show that, in Johannesburg, what is perceived as noise if often determined by social, economic and psychological forces.

## *What is the Soundscape?*

> The word *soundscape* speaks to the physicality of sonic space; it simultaneously conveys a sense of being expansive and contained. Like *landscape*, it suggests spaces and people and at once implies a point of audition and omniscience.
>
> (Sterne 2015: 66)

Auditory perception is inherently panoramic and thus the concept of the soundscape could potentially provide a circumspective interpretation of Johannesburg for which the other senses might not be as well equipped. In the interest of the discussion of the soundscape of Johannesburg that follows, it is important to first provide a theoretical framework for the soundscape itself. For this, I will briefly explain Schafer's distinction between the Hi-Fi and the Lo-Fi soundscape, as well as his what he calls the 'features' of the soundscape and thereafter I will briefly examine Krause's geophony, biophony and anthropophony.

R. Murry Shafer's book *The Soundscape: Our Sonic Environment and the Tuning of the World* (1977) helped to popularise the field of acoustic ecology and brought theoretical lucidity to the study of the soundscape. He begins by introducing three fundamental features of the soundscape namely: keynote sounds, signals and soundmarks. Keynote sounds are the quintessential sounds of an environment, the sounds that necessarily characterise a place. Whereas keynote sounds are generally not consciously heard and most likely fall into the background of everyday auditory perception, signals are consciously listened to and place themselves into the foreground of everyday auditory perception. That signals are actively attended to and are foregrounded is because they are discrete sounds that frequently carry significant meaning for the listener. For Schafer, as we will see below, any sound that interferes with the ability to hear a signal, is classified as a noise. Lastly, soundmarks are sounds that are specific to a community, they are recognised as significant and thus form an important part of the cultural identity of the community. (Schafer 1977: 9-10)

Shafer contextualises the three abovementioned concepts by making a distinction between the Hi-Fi and the Lo-Fi soundscape. For Schafer, the Hi-Fi soundscape is one where signals are more likely to be heard clearly because of the relative absence of noise. "The country is generally more Hi-Fi than the city; night more than day; ancient times more than modern”. (Schafer 1977: 43) Conversely, the Lo-Fi soundscape is a result of an overcrowded sonic environment where meaningful sounds get masked by a sea of superfluous noise. This is clearly a slippery slope because the louder the ambient noise becomes, the louder the signal needs to be. According to Schafer, the historical context for the emergence of the Lo-Fi soundscape is the beginning of the Industrial Revolution, which was then later accelerated by the Electronic Revolution. (Schafer 1977: 71) As a result, the noises to which Schafer is referring are mechanical sounds, sounds of electronic devices and electronically amplified sounds. The combination of these noises results in broadband noise that is typical of the urban setting. (Schafer 1977: 83)

The distinction between the Hi-Fi and Lo-Fi soundscape is critical in understanding the inherent tension between signal and noise. However, before discussing the soundscape of Johannesburg, it is necessary to further elaborate on what distinguishes a signal from a noise and for this Bernie Krause’s book *Voices of the Wild: Animal Songs, Human Din, and the Call to Save Natural Soundscapes* (2015) is indispensable. Krause proposes that the soundscape is composed of three broad acoustic sources, the geophony, the biophony and the anthropophony. The geophony is comprised of “non-biological natural sounds” (Krause 2015: 11) such as the sound of earthquakes, the wind, streams, rain, ocean waves, thunder and lightning, for example. As I mentioned in Chapter 4, that the way these sounds behave in a given environment is determined by factors such as topography and the type of vegetation. The biophony consists of the sounds produced by living organisms and there are many documented cases, which suggest that animals often adapt their sounds to the environments that they inhabit. (Krause 2015: 13) The anthropophony consists of all the sounds made by human beings, that includes music and language as well as noise. (Krause 2015: 12) Although not mentioned by Krause, the anthropophonic acoustics of man-made structures could potentially impede communication because of the “presence of multiple, often parallel, sound reflective surfaces, or urban canyons”. (Warren et al 2005: 498) This means that spaces themselves have an influence on noise levels.

## The Soundscape and History

An illuminating and brief way to understand the spatial evolution of Johannesburg is outlined by Thomas P. Chapman, who divides the history of the city into five morphological stages: the origins of Johannesburg (1904-1919), the development of the transportation grid (1918-1948), the period of high apartheid (1948-1985), the period of the dismantling of apartheid (1985-) and the era of the Corridors of Freedom spatial plan. (Chapman 2015: 77) As one of the proposed themes raised by sound art in Johannesburg, the soundscape and history is important in showing how sound has changed over time and reveals how what we hear today reveals aspects of the past.

The first two decades of Johannesburg were characterised by rapid growth. The discovery of gold by Jan Gerrit Bantjes in 1884 gave rise to a mining camp of 3000 tented diggers that by 1896 had grown into a town of 100 000 people and in 1914 a city of a quarter of a million people. (Van Onselen 2001: 2) The east-west axis of Johannesburg was delineated by the geographical location of the Witwatersrand reef outcrop with its reserves of gold, and thus the spatial manifestation of the city was defined by mining. (Thompson 2000: 120) Early pick and shovel diggers were etching onto the surface a sketch for the spatial plan of Johannesburg, which was a mirror of the subterranean stratum. What sprouted from these surface etchings progressed from tents to corrugated iron structures and eventually to brick buildings. Furthermore, the boom in activity of these early residents was centred around Market Square. This early soundscape was rich in its spectrum of sounds. Van Onselen writes:

> Throughout 1888-1889 the market and its surrounding dusty streets filled with produce merchants, traders, shops, offices, banks, bars, saloons and canteens, and formed the focal point for incoming transport riders as well as members of the digging community who were dependent on food and mining supplies brought into the geographically isolated South African Republic by ox wagon. The clamour set up by all of this human activity competed uneasily – and largely unsuccessfully – with the continuous din of nearby mining machinery to produce a veritable cacophony of sound.
>
> (Van Onselen 2001: 5)

Johannesburg never went through a premodern "age of the ear". (Goldsmith 2012: 44) The clamour and cacophony which Van Onselen evokes is similar to what Shafer calls the “flat line in sound” (Schafer 1977: 78) of the industrial city. The mechanical rock crushing of steam driven stamps incessantly drumming at the earth was a distinctive feature of the soundscape of early Johannesburg. As the hammering ensued, its defining feature was its ceaselessness. The discrete and interrupted listening was replaced by the “clamour of human activity” and “continuous din” of mining. Everything seemed to be presented to the ear at once from all directions and the ceaselessness of the din made it seem as if it had no duration. This mechanical drone of Johannesburg would soon become amplified as the city became increasingly electrified. This introduced even more sound to the city centre.

The Rand Tram was opened in 1890, running from Boksburg in the east to Randfontein in the west, and the first railway line between Johannesburg and Cape Town was built in 1892. (Davenport 1991:184) The first tramways were horse-drawn and ran throughout the centre of Johannesburg. It was only in 1904, with the building of a power station, that they were electrified, and they ran until 1961. In 1888 the railway line stretching from Boksburg to Braamfontein and later to Krugersdorp was built. (Latilla 2018: 32) Schafer describes new sounds that this would likely have added:

> By comparison with the sounds of modern transportation, those of the trains were rich and characteristic: the whistle, the bell, the slow chuffing of the engine at the start, the accelerating suddenly as the wheels slipped, then slowing again, the sudden explosions of steam, the squeaking of the wheels, the rattling of the coaches, the clatter of the tracks, the thwack against the window as another train passed in the opposite direction – these were all memorable noises.
>
> (Schafer 1977: 81)

Initially workers lived in close proximity to their workplace in areas such as Jeppe and Fordsburg or in mining compounds, but gradually they became segregated as a means of social control within the rapidly developing capitalist city that sought to maintain boundaries between workers and employees. Racial and class segregation was not unique to Johannesburg but became a recurrent theme throughout its establishment and was systematically reinforced by successive governments. (Tomlinson et al. 2014: 5) This led to the establishment of white suburbs to the North and black townships to the South and, as a result, a diffusion of the soundscape conjured by Van Onselen.

The rapid growth of Johannesburg was also the result of two other factors: The Native Land Act (1913) and the gradual mechanisation of agriculture. Both forces effectively squeezed black people out of the fields and forced them to move to urban areas, to the extent that in 1936, the population of Johannesburg was just over 500,000. (Thompson 2000: 166) Any morphological reading of Johannesburg cannot avoid the underlying theme of segregation and zoning along racial lines. These spatial divisions meant that any unifying force the Johannesburg soundscape had was undermined by its politically inspired dismemberment. Thus, the soundscape of the greater part of the 20th century of Johannesburg is epitomised by soundmaking defined by distance and separation. The only possible exceptions to this would have been found in the streets of towns and the possibility of auditory overlaying characteristic of intersections such as Park Station or Market Square.

These early antecedents for the spatial plan of Johannesburg were roughly defined by so-called "corridors of sanitation", the earliest of which was arguably the railway line that followed the east-west axis. Mining helped create the topology of Johannesburg where the north-south sprawl is likely a result of the railway division along the reef but also helped shape the city's topography in the form of mine dumps. The language of separate development was manifested in the spatial blueprints of the Urban Areas Act of 1923 for the city that fractured its soundscape into designated acoustic zones of transmission. With few exceptions, the legacy of spatial segregation along racial lines is a major factor in shaping the current soundscape and, as I will explain in the next section (the soundscape and spatial separation), helped to determine which sounds go where.

A notable account of the soundscape of Johannesburg in its convergent, centralised form was made by Barry Marks in his dissertation entitled: *A Noise Level Survey of Johannesburg* (1961). It was written in the vocabulary of spatial language and describes the city in relation to a centre and periphery. The harsh enforcement of these physical and psychological demarcations is testament to the political climate of the time. This is the city as heard on the horizon, a sonic tide breathing to the rhythm of the day-night dyad. Marks measured this in the middle of the day, between 13:00 and 14:00, when the inner city was at the height of cacophonous eruption. Not much reference is made to the kinds of sounds that contribute to his findings, but he does refer to traffic and becomes quite specific about the kinds of engine sounds that are made.


**FIGURE 10: Marks, B. *A Noise Level Survey of Johannesburg* (1961).**

> Street noises consist mainly of that created by motor vehicles, whose capacity to generate noise depends on the speed of the engine, which does not necessarily mean the road speed of the vehicle. Generally speaking most noise is generated at medium road speeds in intermediate and low gears.
>
> (Marks 1961: 3-01)

This is a city epitomised by mechanised mobility and the motor vehicle is the central theme in the sound of its outdoor spaces. It becomes congested by the sound of engines, horns and sirens. Any sounds that the buildings make, and the chatter and footfall of the pedestrians are drowned in currents of gears and pistons.

> The first attempts were made to analyse noise directly, in the vicinity of the Commissioner Street and Eloff Street intersection, with the sound level meter and the octave band analyser. Although this procedure soon received attention from an observant press photographer, it became apparent that if the work was to be completed in a reasonable time, a more rapid method of processing was necessary. The slow rate of progress was attributed to the transient nature of street noise, which could vary by as much as 30 dB within a period of a few minutes.
>
> (Marks 1961: 3-01)

The way that Marks speaks about the "transient nature of the street noise" conjures a soundscape of a city of migrants, here today, gone tomorrow. (Delaney 2014: 97) The "sonorous fabric" (LaBelle 2010: 92) is very loosely knitted, and roughly torn around its edges to create a perimeter. Furthermore, the way that Marks speaks about Johannesburg refers to what people today are more likely to refer to as 'town': the inner city. The fact that he refers to the inner city as Johannesburg and excludes the surrounds raises questions of identity and demarcation. At the time, one would stand outside of Johannesburg and point at an object jutting out with a skyline: *that* was Johannesburg.

In some ways this was a soundscape that had a focal point, with the sonic lava of the eruption flowing into the fringes of Johannesburg. All that is on the fringe is overshadowed by the "thematic activity" (Gurwitsch & Zaner 2010: 408) of the centre. Later, this centralised view of Johannesburg was negated by the spawning of 'edge cities' such as Randburg, first established in 1959 and Sandton, first established in 1969. Such decentralisation set the stage for the function of the CBD as a retail, business and entertainment area to be inverted, in a development where "the periphery *seems* to have become the centre and the centre has become the periphery". (Czeglédy 2014: 28) In the recent past cultural and economic activity has oscillated between these centres, with the rapid growth of the Northern suburbs being in contrast with the revitalisation of the historic downtown core in an attempt to reverse the abandonment of the central business district.

The soundscape of Johannesburg during the dismantling of apartheid is the one that most inhabitants of the city are most familiar with. It is worth postulating that the city centre in particular was similar to that described by de Certeau, a place known by walking. (de Cetreau 2001: 126-133) It was mostly a location for daytime drifting. Walking was often a collective experience, with people zigzagging from one corner of town to the other. Johannesburg became a city of jaywalkers, navigated by word of mouth. The 1990's was a time when the ownership of the inner city of Johannesburg shifted into the hands of an enthusiastic youth, largely impervious to the legacy of segregation. It was, however, difficult to possess the city at night because most of the daytime agents would live in areas that were difficult to travel to and from at night. There was a cut-off point that would prohibit staying until late, unless you were willing to wait for taxis to start operating again in the morning. The soundscape of the daytime was mediated by mobility, fractured by city blocks and contained within the immediate proximity of one's body moving through congested sidewalks. But at night, the city became like a ghost town. The Hi-Fi soundscape was interrupted every so often by pockets of activity, but it was mostly a surreptitious soundscape.

During the past two decades, more and more travel happened by car, especially as a consequence of the growth of the black middle class, and the city became an after-hours destination. The car cut users off from experiencing the soundscape of the environment and isolated them in a capsule. Some of those who did not have cars and walked, also cut themselves off from this experience by plugging their ears with headphones. Office workers were also isolated from the soundscape by locating themselves above horizontally projected street noise and by the insulation of the spaces they occupied. The defence against sound is at times practical and necessary for preserving speech intelligibility in the workspace or hearing loss in the factory. But in other cases, the defence is associated with privilege, such as the quiet capsule of the car and the leafy suburb. Whatever the case might be, something always seeps through.

## The Soundscape and Spatial Segregation

Thus far I have provided a brief historical overview of the soundscape of Johannesburg and have shown how it transformed itself into a mechanised and electrified metropolis, which was accompanied by a population boom – this meant that within a relatively short period of time, an anthropophonic soundscape was superimposed onto whatever soundscape existed before. I showed that the narrative of spatial segregation along racial lines, forming the basic structure for the present soundscape of Johannesburg. This spatial legacy is still evident today and allows us to postulate four general soundscapes for Johannesburg: the black township, the leafy suburb (mainly white residential zones), the industrial zone and the city centre.

### *The Black Township*

The township is a product of ideological design, intended as mass housing where, under apartheid, black workers were forced to live. There are two prominent spatial implications of apartheid ideology both of which bare influence on its soundscape of the township. The first is that it is located far from the city, separated by a "buffer zone" (Murray 2011: 37) or so-called corridor of sanitation that takes the form of shear distance, an industrial area or mine dumps. To me the soundscape of the township then seems just beyond the horizon and most likely travelled to and from by train or by taxi. It is for this reason that perhaps that one of the most notable soundmarks of my experience of the soundscape of the township is that of the train arriving at Naledi station for example, the high-pitched ringing that seems to permeate from the railway lines as the train approaches that culminates in the screeching of its brakes.

The second significant spatial implication of apartheid design is the fact that township homes, for the most part are built in close proximity to each other and the residences are generally much smaller than those of the suburbs. This spatial density, as well as the fact that the inside of the home is often the preserve of the elders, are perhaps the reason that much of the activity in the township spills over into the streets. For example, when I visit a friend of mine who lives in Alexandra, a man is washing his car on the pavement and throws the water into the drain, children are playing soccer and move out of the way for an approaching car, three teenagers sit on the street corner sharing a cigarette bought from one of the many informal traders. It can thus be said that the density and diversity of these anthropophonic street sounds are a keynote feature of the soundscape of the township.

Furthermore, there are also fewer trees in the township than in the suburbs and the city and thus, the residential areas of the township generally lack the biophonic sounds, birdsong in specific, which accompanies lush vegetation. This could be perceived as an audible indication of apartheid spatial ideology. Steve Biko and Jürgen Schadeberg both commented on how the trees represent a "complete" landscape reminiscent of Europe and on how the idea of "completeness" was synonymous with "whiteness" – Biko in relation to the lack of trees in Soweto and Schadeberg in relation to the completeness of Sophiatown. (Beningfield 2006: 215-216) Even in more contemporary readings such as Ivan Vladislavić's *Portrait with Keys* (2007) the edges of Johannesburg are loosely delineated by greenery. The colonial environment is represented by the dominion over and domestication of nature, in opposition to the untended growth on its margins. (Manià 2017: 75-82)

### *The Leafy Suburbs*

I have already made clear my intention to describe the soundscape of Johannesburg from personal experience and I am most familiar with the sounds of the leafy suburb because this is where I grew up and probably spend most of my time. As a result, it is possible to provide a more critical assessment of the soundscape of the suburbs. It is for this reason that I have chosen to focus on two features that mediate the auditory experience of the suburbs, namely walls and trees. Despite some similarities between the township and the leafy suburb, there are also very stark differences. As I have already mentioned, there are audible characteristics of the present soundscape of Johannesburg that are remnants of apartheid ideology. Firstly, the leafy suburbs are in most cases located close to the city centre and secondly, the homes have not been built in such close proximity to each other as in the township. For example, when I visit my friend in Houghton, the foot traffic is policed by a private security company and the pavement is devoid of activity, and the trees are old and large enough to form an archway over the road. I must buzz his intercom to reach him. When inside the walls, we sit in the backyard, by a dilapidated tennis court, and any sound of his neighbours are made absent by the sheer distance from one home to the next, the height of the surrounding wall and the vegetation.

*Walls*

In Johannesburg, the separating device *par excellence*, and often in the most vulgar way imaginable, is the wall. Walls reiterate legislated distance and restrictions on mobility; they represent space as measured: the ordered land exemplified historically by the Group Areas Act (1950), which subjugated society to forced dissection, with the syntax of walls carrying a tyrannical semantic ideology of separation. (Madlalate 2017: 480) Walls, in this sense, are the tools of apartheid measures that, brick by brick, uphold restrictions on movement, one of the essential ingredients of freedom itself. These tensions are famously depicted by Jürgen Schadeberg's photograph *We Won't Move, Sophiatown* (1954), showing three gentlemen sitting on a street corner playing morabaraba, the wall behind them painted with the defiant slogan "We Won't Move".

The remnants of this history are still evident, and their mediator is still the wall, albeit in a less overt and less racialised sense than before. An example is The National Building Regulations and Building Standards Act No. 103 (1977). With reference to boundary walls, the act basically stipulates that walls exceeding 1,8 metres in height are subject to approval from an inspector. Whether or not the regulations are strictly enforced is debatable however, from personal experience, a number of conclusions can be drawn. Firstly, walls have become more prevalent in recent times, secondly, high walls are more prevalent in wealthy areas and, lastly, in locations where the walls do not exceed this height, electric fences, barbed wire or some other kind of sharp contrivance are placed on top.

Walls are defensive structures. Johannesburg is entrenched in an ongoing dialogue between public and private: a war-like dispute in which the boundaries of public and private push against each other. In recent years this has created a conversation of collision in relation to space. Private space tries to legitimise how it continually encroaches on public spaces. In Johannesburg, the discourse of crime is often used as a politically correct euphemism for the same racial segregation. as in the past and, of course, one of the fundamental premises that fuels the expansion of private space and intrinsic defence mechanism, the wall, is crime and safety. (Bremner 2004: 460-463) Walls have both a racial and class dimension because walls require a level of prosperity in order for them to be affordable to build.

> [Walls] emphasise the value of what is private and restricted at the same time that they devalue what is public and open in the city. [Private spaces] are physically demarcated by and isolated by walls, fences, empty spaces, and design devices. They are turned inward, away from the street, whose public life they explicitly reject.
>
> (Caldeira 2000:258)

There is a stark discrimination between the orderliness of the interior and the dark and unpredictable wilderness of the exterior that the boundary wall demarcates. If the boundary wall is a container and the contents of the container are the products of orderliness, all that persists outside of the boundary is by implication uncontained and disorderly. (Connah 2000: 39). The architecture of the interior is then a tool for the subliminal shoehorning of the body's orientation, compelling it to act within the corridors of order. This overlaps with how these spaces are heard. Interior spaces are deadened to simulate privacy and intimacy, and soundmaking is contained within the near distances of close relationships. Public spaces, on the other hand, are formed by the hard, reflective surfaces of the exterior facing walls. This is the reverberation of defence in the contexts of a soundscape imagined as a schizophrenic acoustic space where the voice is constantly reflected back to the source; of corridors where there is no listener, cold and impersonal. The streets *are* corridors but only by virtue of parallel ramparts marking them such, where the sound of traffic serves as an audible manifestation of "new patterns of spatial formation and territorial exclusion". (Dirsuweit & Wafer 2016: 406)

In conclusion, there is a historical dimension to the prevalence of boundary walls in which the disappearance of bureaucratic separation became gradually replaced by private modes of separation. In this context, the boundary wall is the principal mechanism for restricting movement and preserving private social enclaves and, even though walls do have a security dimension, they are also a symptom of social anxiety. This has a direct influence on the soundscape of Johannesburg where home owners and cluster complex dwellers reduce and fragment its richness.

*Trees*

In Chapter 4, I spoke specifically about the acoustic signatures of different natural environments. The landscape in which Johannesburg is built is essentially temperate grassland that has, by human intervention, to a large extent been transformed into temperate forest. The original purpose of planting trees in Johannesburg was to use them for underground wall support in the mines, where beams of wood would have formed columns along the walls of the mine tunnel and would have connected to roof trusses that prevented the roof of the tunnel from caving in. The mines made an effort to select the appropriate tree for the climate and eventually settled on the bluegum (*Eucalyptus globulus*): it grew quickly, was evergreen and suited the climate. (Mondadori 1977: 107) Even though mining might have been one of the reasons for planting trees, the planting of trees in domestic environments was intended to protect suburban dwellers from the supposed harshness of the environment, of which I will speak shortly. By the 1990s it was estimated that there were approximately 6 million trees within the bounds of 'old Johannesburg'. (A Quick History of Joburg's Trees, no date) The idea of the "largest artificial forest" is familiar to most people living in Johannesburg but the trees also signify and reinforce the spatial disparity between Johannesburg and its surrounding areas.

Trees clearly did not only serve a practical purpose. They were also a way of mitigating the harshness of the industrial area and the veld and the garden, as Jonathan Cane shows in his thesis *Civilising Grass: The Art of the Lawn on the South African Highveld* (2016), a way of satisfying nostalgia for the greener pastures of England and Europe. This strikes me as an imagined environment that is made audible through practices such as 'birdscaping' the garden.

There is a stratification of the soundscape that results from the relationship between the density of trees, the ground itself, the layer above the ground and beneath the canopy, the canopy itself and the layer above the canopy. I have already spoken in some detail Chapter 4 about how sound would behave in the forest. What is more important here is the difference in how the behaviour of sound in the city in relation to trees is interpreted. The way that sound is usually discussed in relation to trees is in the context of noise reduction and a detailed discussion can be found in Bucur (2006). The tree belt is most often a boundary of protection between a quiet place and a noisy place. The wind blowing though the leaves and the birds that nest in its branches are audible elements of the tree that represent the boundary "between urban environment and wilderness". (Braverman 2015: 134) Trees not only stratify the soundscape on a vertical level but also begin to set the scene for the dichotomies of distance relations on the horizontal level. Thus, they are a contrived background noise of nature and serenity that represents privacy and solitude: silence and the sounds of nature signify privilege. At the same time, they create an auditory space of quiet, nearness and intimacy where one's thoughts can be one's own.

Within the context of the soundscape of the leafy suburbs, a closer examination of walls and trees reveals how these two features of the leafy suburbs are an attempt to maintain a particular kind of contrived Lo-Fi biophonic environment. This soundscape is a manifestation of the white inhabitants, not only to isolating themselves from the harshness of their environment and preserving a particular social order, but was also a way of reconstructing the European landscape that they left behind. I noted that this environment has an aural component. Walls and trees shape the acoustic signature of the leafy suburbs because walls tend to reflect sound and trees tend to absorb them. The keynote sound is the whisper of the wind as it brushes across the tree's leaves and as a result, for me, the soundmark of the leafy suburbs is birdsong. For the most part, walls serve to insulate this soundscape from the anthropophonic street sounds but, as I will discuss in relation to noise, these sounds often become magnified.

## *The Industrial Zone*

The industrial zone, as in most cities, is located away from places of residence and office work. The sound of the industrial zone is, like most of Johannesburg, also delineated by the rhythms of work, but has very little soundmaking activity before and after working hours as most of the machinery is turned off. There is a pre-eminent hum of electricity, as the fluorescent lights get turned on and the air-conditioning units and extraction fans contribute to this relentless undertone. Mechanical sound is commonplace: stamping, pressing, drilling, grinding, sawing and hammering – the idiophones of manufacture. These sounds are dissected by the occasional electric beeping of a truck or forklift as it reverses to either deliver or collect goods. A small proportion of the materials of production return to the industrial zone for recycling. Opportunistic scavengers sift through garbage bins, sort it and return these materials to recycling plants in the industrial zone. The recycled material is piled to precarious heights on top of a flat trolley and transported over great distances. The sound of these trolley wheels rattling over the road surface has in recent years become a characteristic sound throughout Johannesburg.

## *The City*

A prominent feature of the city is that its sonic rhythms are delineated by the rhythms of work. In general, workers using public transport use the city as a transitory space. The inner-city functions like a transport hub, with transport routes radiating from this central location. There are various taxi ranks such as the ones in Bree Street and Noord Street, and bus and train stations such as those at Park Station and Ghandi Square, all of which are intermediary zones that become highly congested at dawn and then again at dusk. During the hours of economic activity the streets become congested by the staccato horns of taxis, the hissing of a bus's air brakes and the aggravated hooting of drivers. The sounds that accompany retail activity compete for the auditory attention of pedestrians by either amplifying a salesperson's voice, much like a town crier, or by playing loud music. These speakers are often played as loudly as possible, to the extent that the speaker starts rattling and the sound becomes distorted. The ear is drowned in sound and the distance into which listening can be projected is drastically reduced. As the noise subsides at the end of the day, parts of the city turn into a playground, with the rumbling bass of clubs and bars pouring out onto the pavement.

The city as a transitory zone transforms itself outside of work hours into a cultural destination characterised by communality, but this, too, has time limits and from about 02:00 the music subsides, and the city becomes mostly muted. Then the ear can project itself over much vaster distances and the listening experience is heightened. What then becomes immediately evident is how reverberant the city is. There is a hollow quality to the sounds as they bounce off the building walls – a sound quality that one might liken to that of a cathedral. This, too, comes to an end as the whirring of an early morning bus rushing past signals the beginning of an entire symphony that will be repeated.

To conclude, in each of the abovementioned zones – the leafy suburb, the black township, the city centre and the industrial zone – there are of course anomalies in relation to the dominant soundscape. There are clubs in industrial areas, boulevard-like restaurant areas in residential zones such as Melville, Greenside or Vilakazi Street and taverns dotted throughout residential areas. There are manufacturing pockets scattered throughout the city and in some residential zones. There are townships that are inundated with a diversity of sound such as the overpopulated Old Alexandra that is located, in sharp contrast with East Bank, on the other side of the Jukskei River, a quieter residential part of Alexandra. To the west of Alexandra, the township is in sharp contrast with the industrial belt of Wynberg, that is again in sharp contrast with Sandton, which is surrounded by very sparsely populated and immensely prosperous residential zones such as Illovo, Morningside and Rosebank. Here, the mere distance between one home and the next detaches the ear from the communal soundscape. These juxtapositions are found throughout Johannesburg and are part of the highly complex and interconnected soundscape of the city, where separateness is contradicted by the flowing of sound as the city respires to the tempo of day and night.

What sounds tell us about the spatial legacy of Johannesburg is that its borders are fuzzy, porous and less absolute than the spatial divisions would suggest. Sound from one space dissipates into the next. A sound could travel from one space into the next and be reflected back into the space from whence it came. When the sound enters the next space, it would be identified as the sound of the space from which it came, only to become a sound of its origin once it is reflected back.

As one of the proposed themes mentioned in the introduction of this section, it is clearly necessary that the soundscape and spatial segregation needs to be understood in relation to the soundscape and history. Indeed, the compartmentalisation of the city into zones has resulted in four soundscapes that predispose the ear to a particular kind of listening and these acoustic zones of transmission were more clearly defined in the past, when separation was policy. It is likely that these divisions are also evident in other large cities in South Africa such as Durban and Cape Town however, perhaps because Johannesburg is a younger city and developed so rapidly within the context of apartheid political ideology, that these divisions are starker. Although it is beyond the scope of this study, it will also be important to situate this audible past in the context of other cities of the global south that are also characterised by social inequalities.

Johannesburg itself is constantly changing. I mentioned how the spatial legacy of the city is continuously undermined by sound that draws attention to the porosity of the borders between different areas. Listening to Johannesburg, it becomes audibly evident that these zones have become less and less absolute and that physical separateness is constantly contradicted by sound, irrespective of the defensive measures taken against the penetration of sound. In what follows, I would like to propose how that the perception of noise could potentially reveal the friction between one zone and the next as well as the soundscape of the past and present.

## The Soundscape and the Perception of Noise

Schafer and Krause have already provided a basic understanding of noise. For Schafer, noise is anything that interrupts the signal or interferes with the reception of meaning and for Krause; noises are anthropophonic sounds that are “chaotic or incoherent”. (Krause 2015: 12) This basic understanding has thus far been sufficient: however, a more detailed description of noise is now necessary. I will begin with an analysis of three different uses of the word ‘noise,’ and thereafter discuss three different instances that inform what is generally perceived as noise. The aim of the discussion that follows is to suggest how noise can be interpreted to reveal the historical and spatial aspects of the soundscape of Johannesburg.

According to David Novak, the word 'noise' could be used to refer to three different phenomena. The first proposition is that noise is a "property of sound". (Novak 2015: 125) This suggests that there is something qualitatively noisy about a particular sound. What constitutes noisiness is determined by which sounds are perceived as musical and which are perceived as non-musical; where musical sounds are pleasurable and non-musical sounds are not. I discussed this in more detail in Chapter 2. The second proposition is that a noise is "a distinct sonic object within music, speech or environmental sounds". (Novak 2015: 125) This suggests that noises are different from and an interruption of sounds. Whereas sounds are coherent, intelligible, have meaning and are not harmful, noises are chaotic, disrupt meaning and are harmful. The third proposition is that noise is used as "a totalising qualifier for emergent styles". (Novak 2015: 125) This suggests that a new type of music is called 'noise' – there might not be anything inherently noisy about the music itself and often referring to the emerging music of a particular community as 'noise' makes an association between the negative perceptions towards noise and the particular community. In my view, the idea of 'noise' used as a "totalising qualifier" can be extended include the soundmarks of particular communities too. Having proposed three different phenomena to which the word 'noise' commonly refers, in what follows I will discuss the perceptual mechanisms that determine how sounds become classified as noises.

### *Disrupting the Habitual Auditory Ambiance.*

Much of what is considered as noise depends on context. Auditory perception, as I have shown earlier in this chapter, tends to adapt to the spatial and temporal continuity of a given acoustic environment. It is likely that a sound would be classified as a noise when it disrupts the perceptual continuity of a familiar acoustic environment. Below, I will discuss how sound could disrupt the perceptual continuity in relation to space and time.

Firstly, in the sonically cluttered spaces of Johannesburg, the scope of which sounds would be considered unfamiliar becomes dramatically narrower. In spaces such as Bree Street Taxi Rank, the ear acclimates to expect the unexpected. Conversely, in the sonically sparser spaces of Johannesburg the scope of sounds that would be considered unfamiliar becomes broader because the ear acclimates to a relatively predictable range of sounds. This is the case with the leafy suburbs. The likelihood of a sound being experienced as an abrupt disturbance depends on the degree to which the ear has acclimated to the ambient sounds of certain spaces.

Secondly, there is a temporal factor. The general view of urban noise does not always account for the rhythm of urban soundmaking. For example, if asked to identify the noisiest areas in our city, the immediate response is likely to be that these are the industrial areas. This is probably true for their daytime activities but at night they are likely to be the quietest of all urban areas. Similarly, residential areas are noisier during peak hour traffic in the morning and late afternoon and during the week, and the daytime is quieter than daytime over the weekend. This flow of activity based on work, travel and leisure, oscillates between noise and quietude to a very predictable rhythm. The ear becomes attuned to the temporal continuity of the city. When a sound disrupts this continuity, it will most likely be considered as noise.

Furthermore, the temporal continuity of sounds and the likelihood that the sound will be classified as a noise is also determined by the spectral complexity of a sound. The spectral complexity of a sound refers to the range of frequencies presented to the ear over a given time period. If a sound contains an audibly complex range of frequencies within a short space of time, it is are more likely to be thought of as noise. (Kryter 1970: 271) Importantly, the measurement of the spectral complexity of a sound or particular acoustic environment is independent of the meaning of the sound.

## *The Perception of Noise as Harmful*

The most widespread conception of noise is that it is harmful. That prolonged exposure to noise contributes to hearing loss is a well-established fact. A full account of this is given in Karl Kryter's book entitled *The Effects of Noise on Man* (1970). However, what is often missing from empirical approaches to noise is how the perception of noise as harmful is often used to justify the protection of particular sonic environments. As is evident in both Schafer and Krause's work, mentioned earlier, the sounds of technological media are deemed undesirable and characteristic of the built environment.

However, Novak questions this by stating that noise can also refer to some of the sounds of nature. (Novak 2015: 129) For example, John Cage points to this in an interview with Laurie Anderson for *Tricycle Magazine*. He draws a comparison between the sounds of the city and the sounds of the country, particularly the sound of traffic as compared to that of birds. Perhaps because the prolonged exposure to the sound of traffic has desensitised Cage and the sound of birds are relatively unfamiliar to him, Cage finds the birds noisy, comparing the sounds they produce to that of sirens. (Cage, quoted in Coe 1992: Taking Chances)

The extent to which the "technologically produced field of sound" (Novak 2015: 129) and anthropophonic sounds in general, are considered to be harmful is primarily determined by their amplitude and duration. There are numerous methods for measuring noise levels that are well documented in Peterson and Gross' *Handbook of Noise Measurement* (1963). In Johannesburg this is enforced by the Environment Conservation Act, 1989 (Act 73 of 1989) (Appendix Item: 4). The act regulates loudness in relation to the ambient sound level of a particular location and defines noise in loose terms; it also refers to recommendations by the South African Bureau of Standards (SABS 0103): *The Measurement and Rating of Environmental Noise with Respect to Annoyance and Speech Communication* (1997). The act also makes provision for what it calls a noise nuisance, which, at first glance, includes almost everything that pertains to human activity in the urban environment and can be read as a taxonomy of the soundscape of Johannesburg.

Without detailed and up-to-date data about the noise levels of Johannesburg over time, it is difficult to determine the impact of noise on the environment and on the hearing of people. Clearly measuring the amplitude and duration of sounds is a limited means of determining why some sounds are classified as noise. Furthermore, measuring loudness in decibels bears little relation to perceived loudness. For this, researchers use a unit of measurement called 'sones'. To measure sones, a reference tone of 1000 Hertz is played at 40 decibels: if a sound is reported to be three times louder than the reference tone, then the sound has a perceived loudness level of three sones. (Peterson & Gross

1963: 18) How the perceived loudness of a sound relates to what Kryter calls "perceived noisiness" (Kryter 1970: 169) will be discussed in the next section.

Recalling the four different soundscapes identified earlier, it is possible to observe how industrial noise creates a sonic barrier between the leafy suburbs and the township. Indeed, acoustic walls such as those created by the industrial zone as well as busy roadways, demonstrates how noise in Johannesburg is used as a means of reinforcing spatial segregation. However, that noise is perceived as harmful also influences the spatial formation of the city, which Novak recognises:

> As noise was brought further into social consciousness, its recognition contributed to the inexorable fragmentation and privatisation of urban space, through zoning, sonic surveillance, and acoustic shielding from public noise.
>
> (Novak 2015: 129)

In conclusion, the view that man-made sounds and particularly those produced by technological media are more harmful than the sounds of nature, is debatable. Because of the lack of formal up-to-date research it is difficult to determine which are the noisiest parts of Johannesburg, what the impact of noise is and how this has changed over. Lastly, the perceived harm caused by noise makes some of the spatial characteristics of Johannesburg more apparent.

## *'Perceived Noisiness'*

Thus far, I have proposed how sounds can potentially be classified as noises when they disrupt the habitual auditory ambiance and when they are perceived as harmful. The third and final factor pertains to the social, economic and psychological forces that cause individuals and communities to classify certain sounds as noise and others not. This approach attempts to disentangle what is 'empirical' from a web of personal and communal experience. By focussing attention on how learnt associations and attitudes to certain sounds determine why they become classified as noise it becomes apparent that noise, and the terms with which it is associated such as 'annoyance', 'nuisance' and 'undesirable sounds', are socially constructed.

In his book *Urban Sound Environment* (2007), Jian Kang looks at environmental and demographic factors in relation to the classification of noises. This approach defines attitudes towards sound and noise within the spectrum of social, psychological and economic factors and suggests that there are five factors that influence how certain sounds are interpreted as noise and others not.

The first factor is fear and danger. When sounds are associated with events that could have negative effects on our physical well-being or are associated with harmful situations, they are immediately perceived as annoying. In some cases, this is a consequence of the event, such as in the case of explosions or crashing sounds; in other cases the sound is deliberately intrusive, such as the sound of a siren or alarm. Of course, there are many sounds that are associated with fear and danger that are not noises, such as the sound of a tree branch brushing against a window.

The second factor is related to the cause of the sound and to what degree regulatory provisions are effective in noise abatement. How legislation works towards silencing the environment, community perception and economic activity is the result of a tricky negotiation. In short, if a community is not economically dependent on the sound source, they are more likely to perceive it as noise and more likely to complain. This changes when a community is economically dependent on the sound source.

The third factor is noise sensitivity. A community that lives in a generally noisy environment such as the inner city is more likely to become desensitised to certain sounds that might be annoying than a community living in a quieter environment.

The fourth factor is related to interruptions and was hinted at earlier in our discussion. The literature often cites interruptions as having an effect on speech intelligibility, but this could include any activity that is interrupted by a sound. Such sounds are likely to be viewed as noise.

The final factor is the perception of the environment. If certain sounds are related to activities that are harmful to the environment, they are likely to be viewed as noise. (Kang 2007: 23)

The dynamics between these five attitudinal considerations allows us to get a broad idea of why some sounds cross the threshold and become perceived as annoying and others not. These broad factors are helpful in explaining subjective experience. A limitation, however, is that the approach treats society uniformly and fails to make finer distinctions.

One way of overcoming this generalised view is by accounting for demographic factors. Here, a correlation is drawn between factors such as population density, age, gender, ethnicity, social bonds, level of education, economic factors and property ownership and the likelihood for a person or community to become annoyed by a specific sound and thus classify it as noise. (Kang 2007: 24-25)

What emerges from looking at demographic factors and noise is that social cohesion, personal space and proximity to other people are relevant factors. It seems that people have the propensity to think of their personal auditory space as their personal physical space. On the one hand, the auditory experience can seem enmeshed in what LaBelle calls the “sonorous fabric” (LaBelle 2010: 92) of the city, in which case certain spaces in Johannesburg would serve as a catalyst for social and cultural cohesion; on the other, it might seem as if there is an assault on our personal auditory space, in which case sounds intruding upon it would cause an experience of repulsion and a desire to untangle oneself from the sonorous fabric.

Another factor that Kang neglects to mention is cultural difference. It has been found that in many cases the interpretation of what is deemed noisy varies from one culture to another and is relative to what the so-called noise is associated with. For example, whereas German subjects associated the sound of a bell with a church bell, Japanese subjects associated it with a fire engine. (Neuhoff 2004: 186-187) The study did find that there were some cross-cultural views on what is deemed noisy, and that one of these sounds is the sound of a siren.

Clearly the soundscape as expressed by Schafer and Krause does not do justice to the many complexities that a closer analysis of noise reveals. In this section, I have attempted to show how some sounds are perceived as noise because they either disturb the habitual auditory ambiance, are perceived as harmful or are perceived as noise as a result of social, psychological and economic forces. Three insights were gained: that the experience of noise is almost always contextually bound; that awareness of noise has contributed to the spatial fragmentation of the city; and that sounds often become classified as noise because of what they signify. It also became apparent that the social construction of noise has a large influence on individual perception of noise. In my view, noise can also be an important indicator of how past spatial relations of Johannesburg collide with those of the present. Thus, for a sound artist working in Johannesburg it will me important to recognise how the perception of noise could expose instances where spatial divisions are being upheld and protected; but also, to acknowledge instances where these divisions have dissolved or are in the process of doing so.

## Sound Field Analysis

The established notion of the soundscape is misleading. It is derived from the visual term 'landscape' and immediately makes one think of the soundscape as a 360-degree panorama-like scene in sound, where sound travels from the furthest stretches of the horizon and converge at one's ears. Although there is a level of truth to this, it implies an exclusion of discrete spaces that may also be isolated. The sound of these spaces also belongs to the soundscape. For this reason, it is more useful when speaking of the sound of Johannesburg to, wherever possible, replace the term 'soundscape' with the term 'sound field'. Even though the terms are often interchangeable, 'sound field' is better attuned for referring to a particular set of sonic circumstances.

To this end it is also useful to make a distinction between microscopic and macroscopic sound fields (Kang et al. 2016: 162), as well as to understand the microscopic and macroscopic sound fields as relative to one another. To illustrate this: the sound field of Park Station is a microscopic sound field in relation to the macroscopic sound field of Johannesburg as a whole, and so is the sound field of a single train coach is microscopic in relation to the macroscopic sound field of the train. These relationships can continue *ad infinitum.* Of course, this is a hierarchical means of articulating the soundscape, but it does assist in contextualising the sound of Johannesburg in relation to the space or site in question.

Cartographical information seems to be a fruitful starting point for describing sound fields within the context of space in Johannesburg. With this in mind, there are various ways of making sound maps, some objective and some subjective, some looking particularly at the form of sound and others at its content.

At the one end of the spectrum there are sound mapping methods that look at the form of sound, one of which I already mentioned in discussing Marks: the noise level survey. The noise level survey measures decibels at a fixed set of locations during a predetermined time of day with the aim of calculating the average ambient sound level of a particular space. Marks' methodology stipulated that he made measurements between 13:00 and 14:00 and this he duly did over a series of days, measuring from street intersection to intersection. The methodology can be modified, however, to measure, for example, the loudest times of day at one particular intersection. Another application is in the manufacturing, construction or mining industries, where workers wear sound level meters that track their exposure to sound, thus charting the noisiest spaces based on movement and routine.

Marks' study is more than 50 years old and even though it does evoke an image of the sound field of Johannesburg, a present-day picture of the noise levels of Johannesburg is absent.

Although the noise level survey is a very useful in determining the loudness or softness of spaces in relation to times of day, whether as stationary measurements or as chart of our movement in and out of loud sound fields in Johannesburg, it is not meant to account for the subjective experience of loudness. For this, a similar methodology to the noise level survey can be adopted, but the measurements taken are not made with a sound level meter but with the ear. Some spaces might seem louder and others softer. Similarly, the same space might seem louder at a particular time of day and softer at another. This type of measurement can also be a group exercise where some people in the group might determine that a space is loud and others in the group might not.

Even though the noise level survey, whether objective or subjective, does provide us with an idea of the sound of spaces, it treats all sounds as if they were the same. A helpful way in which to map the content of the sounds of a particular space or site is to categorise sounds in relation to a timescale. These categories are not fixed but Kang et al suggest general guidelines:

| **Sound Category** | **Major Sound** | **Code** |
|---|---|---|
| Human Sound (Hum) | Child Voice | CS |
| | Adult Voice | AS |
| | Footsteps | FS |
| Mechanical Sound (Mech) | Airplane Flying | AF |
| | Bicycle Riding | BC |
| | Bell Ringing | BR |
| | Construction | CT |
| | Emergency | ES |
| | Grass Mowing | GM |
| | Music | MS |
| | Ship Moving | SM |
| | Other Mechanical | OA |
| Traffic Sound (Traf) | Train Moving | TM |
| | Traffic Sound Foreground | TSF |
| | Traffic Sound | TSB |
| | Motorcycle Rumbling | MSR |
| Geophysical Sound (Geo) | Grass Rustling | GR |
| | Raining | RS |
| | Sea Wave | SW |
| | Tree Rustling | TR |
| | Wind Blowing | WB |
| | Water Sound | WS |
| Biological Sound (Bio) | Birdsong | BS |
| | Chicken Clucking | CC |
| | Dog Barking | DB |
| | Frog | FR |
| | Insect | IS |

(Kang et al. 2016: 162)

Above, the codes are merely shorthand: any kind of abbreviation or symbol can be used; it's a matter of personal preference. A timestamp is then ascribed to each sound and a thematic overview can be given of a particular space, set of spaces or even a sound walk or sound walks. Evidently the subcategories are not exhaustive, but the system can be adopted to suit a particular location. The subcategories can also become more specific. For example, traffic sound can branch into engines, horns, screeching tires, the sound of windscreen wipers and so forth. The system is designed with the purpose of providing a thematic overview of a particular space or site and is a useful way of initiating conversations about sound fields by means of data collection, even if only at a cursory level. The simplest way to do this is to make a recording and chart the sounds along a timeline. The recordings can be made of the same space at different times of day to obtain microscopic sound field information or at different spaces to obtain macroscopic sound field information. Using this system as a starting point, it is also possible to add more specific directional information about the sound field using a fixed set of orientating information that describe where particular sounds are emanating from.

As useful as this system is in describing the sound fields of specific spaces, it does not yet account for the way that the sound field of the space in question is experienced by people. For this I turn to what might be called a phenomenological approach to sound field analysis. In this case, when entering a sound field, we can take note of our experience of its sounds. Below is a provisional set of questions that can be used to formulate one's own.

1. Write a list of the sounds you heard. How many did you hear?
2. Does the space sound big or small?
3. Is the space quiet or noisy?
4. Which sounds did you notice first?
5. Which sounds were near, and which were far?
6. Which were in the foreground and which were in the background?
7. Did you move nearer to some sounds and further away from others?
8. Did some sounds approach you and did some move away from you?
9. Which sounds predominated: mechanical, human, traffic, natural or bioacoustic ones?
10. How did certain sounds make you feel?
11. What did certain sounds remind you of?
12. If the sound of the space were a colour, which would it be?
13. Thinking about the sound of the space, draw it as a shape.
14. Describe the personality of the space.
15. If the sound of the space had a particular body language, how would it look?

Much of this all seems very psychoanalytical, perhaps because it ultimately is. The point is to attain information, whether descriptive or interpretive, about the experience of the sound in a space and essentially stimulate a description of sounds as if they are being heard for the first time. This process can be extended to produce a personal sound journal, where one either goes to the same space at the same time every day or accounts for one's sonic experiences over the course of a day. What is the first sound you remember hearing today? It is also an effective way of determining how a group of people experience the sound of a space. This is often done by blindfolding the group, but this isn't always necessary. Notes can also be taken during the listening session or after the listening session. After the exercise it will also be useful to discuss the results with the group.

To summarise, there are various forms of sound mapping that can be used as a starting point to describe the sound field. I have only mentioned four within the context of objective and subjective ways of mapping. That we have this information might at times be enough to reveal something about the space that we might not have registered or thought about before, but there are also many paths down which mapping the sound field might lead us. In the final section of this chapter I will discuss some practical examples as well as sound artworks informed by the sound field of a space.

## Applied Soundscape Studies.

In this section I will be discussing 4 projects: the first located in Brighton & Hove, the next in Dublin, then one in Antwerp and finally a project located in various locations in Italy.

### *Brighton & Hove*

As part of an all-night arts and cultural festival entitled *White Night*, Harry, J. Witchel took the West Street Tunnel in Brighton & Hove as a starting point for a sound art intervention within the context of human behavioural analysis. The project was centred on concerns about the way in which loiterers in the tunnel made it uncomfortable to use. With this in mind, Witchel conducted a series of experiments by playing music in the tunnel and observing how this affected the behaviour of people in the tunnel, looking particularly at the length of time that a person or persons would spend in the tunnel and the speed at which they walked as a function of the music that was played. The central question was whether music would encourage loiterers or drive them away, in comparison to having no music playing. Witchel installed cameras in the tunnel to track the behaviour and various types of music were tested. The sum of his findings

was that, at one end of the spectrum, electronic/dance music would attract loiterers and people's walking speed would decrease resulting in them spending more time in the tunnel.

At the other end of the spectrum, classical music, Handel in particular, would deter loiterers and people's walking speed would increase, meaning that they would spend less time in the tunnel in comparison to when there was no music playing at all. The study proves more than that Handel is like auditory teargas; it demonstrates the ability of sound to attract and repel people. Within the context of urban spaces sound can be a powerful tool in reclaiming spaces or tailoring the ambient sound in ways that suit their use. In this sense, perhaps there are spaces in the city in which loitering would be more acceptable and therefore one could, in theory, tailor the ambient sound accordingly. (Lavia et al. 2016: 251-255)

### *Dublin*

In 2013, the Dublin City Acoustic Planning and Urban Sound Design Programme was started by artist Sven Anderson. The programme is an interdisciplinary soundscape project that involves urban planners, designers, city managers and architects. The project is based on a broad set of goals rooted in a collaboration between different sectors involved in urban planning and design and aimed at creating awareness of the importance of sound in the urban setting of Dublin. There are various ways in which the programme manifests itself such as the writing of a manual for acoustic planning, field recordings, a website linked to a real-time noise level monitoring system and sound installations.

The two sound installations are entitled *Continuous Drift* (2014) and *Glass House* (2014). *Continuous Drift* is a permanent interactive sound installation at Meeting House Square and plays different sonic atmospheres that are controlled by the mobile phones of the people in the square. (Anderson, no date: Official Website) *Glass House* (2014) is located at the Smithfield Plaza and there one can listen to the melodies played during film screenings inside the adjacent Light House Cinema. The installation projects these melodies into the plaza at ambient levels. Although the piece is a permanent installation, it plays intermittently, during screenings. (Glass House: 2014) What is significant about Anderson's work is how it shows that the collaboration between various urban actors and research-driven soundscape practice can work towards a sense of ownership of the urban soundscape. The real-time noise monitoring system itself is something that could be beneficial to a setting like Johannesburg. (Dublin City Sound Levels, no date)

### *Antwerp*

Anderson's work is important in how it demonstrates the potential for sound art and urban space within a collaborative framework to find ways to create new forms of aurality, which can be site specific and artistic as in the case of the sound installations or dispersed and functional as in the case of the Dublin City Sound Levels. The only downfall of this way of thinking about the soundscape of the urban environment is that it intervenes after the fact. The sound installations are retrofitted, and the sound level meters give an indication of sound that not much can be done about. In an attempt to circumvent this challenge, Dick Botteldooren and Bert De Coensel suggest that the interdisciplinary approach, that include sound attentive strategies, should begin during the early stages of urban planning, as is the case in Antwerp. The work of Botteldooren and De Coensel is focused on how soundscapes can influence the psychological well-being of the users of different spaces and to this end, they intervene at the early stages of urban development in ways that impact design. Their motivation is geared towards optimising the kinds of sound that create tranquil spaces and thus arranging space in ways that encourages natural sounds, such as the sound of birdsong and running water, and filter out urban noise such as traffic. Central to this approach is the sound map that forms the basis for a hypothetical set of recommended strategies that designers could follow to encourage green spaces. This early stage intervention is important, and one can only imagine how it could be realised on a large scale. What is missing from this, however, is the artist's touch. There is a lot of potential for work like that of Anderson in relation to large scale urban planning: one could potentially see whole urban areas become sound installations. The soundwalk itself could then be dominated by the haphazardness of urban sound but be a finely crafted aesthetic experience.

### *Italy*

The project discussed here is by Luigi Maffei, Giovanni Brambilla and Maria Di Gabriele and documents the soundscapes of Italy with the underlying premise that certain soundscapes form part of the cultural heritage of Italy and should thus be preserved. The starting point of the project was the UNESCO International Convention for the Safeguarding of Intangible Cultural Heritage and the question why sound was not considered a significant enough factor to validate its preservation. The study focused on various folk music festivals in Italy to demonstrate the diversity in rhythm and voice and how these are sound markers of a particular area.

There are many projects that emerged from the UNESCO convention and many of them relate to either music, such as the Safeguarding of Traditional Music in Ethiopia or sound, such as The Safeguarding of Female Chants in Morocco. At the heart of projects of this kind is soundscape mapping. There surely are sounds that form part of the intangible cultural heritage of Johannesburg but none have yet warranted recognition by UNESCO. (Lavia et al. 2016: 251-255)

### *Conclusion*

Looking more deeply into the perception of sound can provide a foundation for an exploration of Shklovsky's idea of "making it strange". It is thus important to make mention, by way of conclusion, of some of the ways in which sound art can intervene in the sphere of automatic and habitual auditory perception with reference to Johannesburg; how it can "intensify the impressions of the senses". (Shklovsky 1990: 3) In relation to the temporal experience, mention was made of how sound can extend the experience of duration within the so-called "specious present" and how this moment unfolds as a dialogue between the sense of foreknowing and forefeeling. In Chapter 6, we will see how Bettina Malcomess' tape loops draw out the length of foreknowing by remaining in the listener's memory long after the loop has stopped playing.

In this chapter an important phenomenon inherent to auditory attention was mentioned: how gesturing towards silence intensifies the experience of the background. This is the case in Bill Fontana's *Acoustical Visions of Venice* (1999), also to be discussed in Chapter 6, where the ear projects itself towards the horizon and all the sounds that prevent it from reaching its destination are accentuated. The work also reminds us of another means by which sound art can potentially intervene, by disrupting the continuity of everyday listening.

Sound and motion are another means by which the auditory experience can be made strange. This is the case with soundwalks and field recordings. Whereas in the former case, sounds are recorded while walking but listened to from a stationary point, in the latter case the recording is made from a stationary point and the motion of the sounds moving around the microphone is accentuated. The experience of architectural space can also be a starting point for mediating in unexpected ways, as in the case of *The Dublin Soundscape Project* and the work of Sven Anderson. Lastly, the way in which sounds are described could in itself become a means of roughening the surface – and here, a number of provisional suggestions in the context of sound field analysis are made.

# CHAPTER 6: SOUND ART IN JOHANNESBURG


**Figure 11: Neuhaus, M. *Listen* (1979)**

One aim of this thesis has been to function as a primary resource for sound art in Johannesburg. In order to introduce and bring lucidity to the essential conversations surrounding sound art, I have assembled a spectrum of secondary research. This provides important insights for conducting more informed investigations into sound art in Johannesburg and related practices. In searching for the roots of sound art it became clear that sound art was mainly a Western phenomenon. With this in mind, it is important to recognize that the influence that auditory culture in South Africa has had on the emergence of sound art in Johannesburg, is itself an emerging discipline. For example, the long history of field recording, the rich and diverse musical heritage, film sound, radio and theatre in South Africa, to name but a few, would be important for future scholarship to draw on. My personal contribution to this emerging body of research has been to review sound art in Johannesburg. This began in 2005 when I started writing my master's dissertation entitled *Sound Art in Johannesburg: A Critical Review 2005-2009*.

One role of sound art in Johannesburg should be to draw attention to auditory experience by foregrounding the experience of space and time. This might reveal matters relating to the soundscape that emerged in the previous chapter, particularly because those are the sounds we share. In this chapter, I will extend my previous survey of sound art in Johannesburg, firstly by extending on the analysis of sound artworks and secondly, by surveying works I deem significant since 2009. The section on the analysis of sound work will account for two key considerations namely, documentation and description. Thereafter, I will survey a select group of works whilst reflecting on their significance to the emergence of sound art in Johannesburg. In surveying these works, I propose four categories of related case studies in each:

1. **The Physical Properties of Sound**: *Towards a Definition of Sound as Vibrant Matter* (2016) by João Orecchia, and *Vibrationology: Searching for Resonances in the Sonic Architecture of Matter(s)* (2019) by Daniel Bruce Gray.

2. **Field Recording**: *LOS-JHB* (2015) by Emeka Ogboh and *Third Space* (2013) by Malose Malahlela

3. **Voice**: *Echolalias* (2016) by Bettina Malcomess, and *Slaap my kindjie, slaap sag* (2013) by Pauline Theart.

4. **Musical Performance**: *For the pianist's eyes only* (2010) by Jill Richards and Jem Finer, *Vehicle* (2018) by Gerhard Marx, and *Hlabelela: It's a New Mourning Nkush* (2016) by The Brother Moves On.

To identify some characteristics of sound art in Johannesburg as a whole, the survey will be concise and not comprehensive, with the broader aim of asking to what degree these works expose aspects of shared auditory experience in Johannesburg. I intend the final section of this chapter as a thought-provoking reflection on the roots of sound art, focussing particularly on the experience of time and space, and asking how sound art in Johannesburg could introduce itself to this conversation.

## Analysing a Sound Artwork: Some Key Considerations

Studies in sound are either quantitative, such as Marks' noise level survey or qualitative, such as the review I conducted for my Masters, or a combination of both quantitative and qualitative research methodologies. When analysing works in sound, the experience of the actual work, reproductions of the work or literary accounts of the work, are all relevant. Within the context of phenomenological analysis, this is what Husserl might call intentional analysis, which reports on "how" and "what": "*how* experiential processes proceed and *what* is experienced through them". (Wertz 2011: 126) Therefore, the survey that follows is based on phenomenological reflection of the work itself, but also on recordings and literary documentation. The groundwork for analysis of sound artworks, regardless of the chosen methodology, should begin by becoming familiar with questions of documentation and description. Below, I will introduce both.

### *Documentation*

Documenting sound artworks poses interesting questions. Sound works often refer to the time and space of a particular experience, and when the moment passes, so too does the artwork. Works often have an afterlife in memory, literary documentation or recordings. Recording is documentation of a specific time and place and allows the work to be relived and reproduced almost indefinitely, through playback. I showed, in Chapter 3, that the art of recording is never a neutral affair, because microphones and speakers determine the nature of playback. Because sound is an ephemeral medium, documentation is important in how the works echoes beyond the immediate moment. At times the documentation itself is the artwork, blurring the lines between direct and indirect experience of the sonic event.

### *Description*

In Chapter 3, I showed how sound art emerged from the convergence of music and art within the context of recording and playback technology. Thus, when describing a sound work, I propose that an interdisciplinary approach be deployed, drawing on music and art and sound engineering, acoustics and soundscape studies. When one first encounters a sound artwork, the immediate inclination is to describe both observable features and the auditory experience of the work. In this section, I will discuss the observable features of sound artworks by reflecting on my Master's dissertation and the auditory features by introducing Peter F. Ostwald's suggestions on making statements about sound.

While reviewing works during the writing of my Master's degree it was necessary to provide a provisional framework for the analysis of works. Perhaps because I had been working on a series of sound installations, I emphasized what I heard and what I saw. Below, I provide a summary:

> 1. The Medium: Is the sound produced by acoustic or electronic means or a combination of both? If electronic, is it produced by analogue or digital means or a combination of both? What kind of recording and playback device is used? Were any devices used to modify the sound? What are these devices?
> 2. The Method: Is the sound played by a performer or is it pre-recorded? Was the recording made in a controlled environment like a studio or was it made without insulation from environmental sounds. How were the microphones used? Were they stationary or in motion? How is the sound being transmitted? Where are the transmission devices placed? Are the sounds stationary or do they move across different transmission devices?
> 3. The Site: Is this an indoor or outdoor space? What are the features of the space into which the sound is being transmitted? Is it large or small? What are the acoustic qualities of the space?
>
> (Engelbrecht 2010: 35-40)

The observable features are secondary to the sound itself; however, they provide valuable insights. In Chapter 3, I noted that speakers and microphones are instruments. Speakers project sound into a particular span of space, and microphones capture sound in space over a particular period. Technology itself is passive, but how the sound artists make use of it, imbues it with meaning. Thus, which speakers or microphones are used and how they are used to foreground the experience of space and time are aspects of the work that can often be observed (except for sound works in darkened rooms). Types of speakers, microphones and audio devices are plentiful and well documented elsewhere and I therefore I will not deal with them here.

Observable features aid in describing works in sound, but only to support describing the sound itself. I have already proposed an interdisciplinary approach. Here, it is important to be aware that certain concepts refer to the same phenomenon across disciplines while others reveal contradictions. For example, the foreground/ background relation refers to the same phenomenon in music as it does in art; however, scale means something different in art than it does in music. Given the potential vastness of this topic, I will summarise the seven qualitative attributes proposed by Peter F. Ostwald in his book *Soundmaking: The Acoustic Communication of Emotion* (1963):

1. **Rhythmicity**: Are the sounds rhythmic or irregular? Whereas rhythmic sounds recur and repeat in a predictable pattern, irregular sounds have an unpredictable pattern.
2. **Intensity**: Are the sounds loud or soft. Loud sounds are experienced as loud and soft sounds as soft, but this is also in relation to other sounds such as the ambient noise level.
3. **Pitch**: Are the sounds high- or low-pitched? This is based on the frequency of an acoustic vibration discussed in more detail in Chapter 4.
4. **Tone**: Are the sounds tonal or noisy? Whereas tonal sounds consist of a single vibratory frequency, noisy sounds (not to be confused with unwanted sound), comprise a combination of frequencies and produce complex waves.
5. **Speed**: Are the sounds fast or slow? Perception of speed is a combination of intensity, pitch and tone. When successive tones are played rapidly, they are perceived as one sound but when they are played less rapidly, we are able to perceive them as separate sonic events.
6. **Shape**: Are the sounds impulsive or reverberant? The shape of a sound is determined by its envelope. The envelope is comprised of a sound's onset time, its growth, its steady state, its duration, its decay time and its termination time. When all of these factors are considered a sound can either be impulsive, such as a blip or a short beep or reverberant such as a handclap in a large in a large parking garage.
7. **Orderliness**: Are the sounds compact or expanded? Whereas compact sounds have a recognizable pattern, expanded sounds seem chaotic. Unlike rhythmicity, which is a biological mechanism, orderliness is learnt. Thus, before one learns to recognise the orderliness of a foreign language, it seems chaotic or expanded. (Ostwald 1963: 25-30)

Although this is a cursory introduction, Ostwald's seven points are useful because he sets up a series of gradients that makes it possible to describe individual qualities of sounds. However, one of the pitfalls of this approach is that it neglects the contextual attributes, Idhe explains:

> To simply take the thing alone without raising the wider question of how things present themselves in terms of a situated context is to allow the illusion of a thing-in-itself to occur. The thing never occurs simply alone but withing a field, a limited and bounded context.
>
> (Idhe 2007: 73)

Perhaps then another gradient can be added to Ostwald – Reception: Is the sound public or private? Whether or not a sound artist pays any mind to the sound of their immediate environment, the soundscape persists. Do they then choose to conceal or reveal the sounds of the environment? To acknowledge "situated context" (Idhe 2007: 73) as a significant feature when discussing works in sound, would then require attention to the various acoustic zones of the soundscape of Johannesburg, mentioned in Chapter 5. Where, in relation to the soundscape of Johannesburg, is the work located? Does the work attempt to mask the ambient sounds of its immediate environment? What does moving from the soundscape of a particular environment into earshot of the work reveal? What will become clear is that, in most of the works I review, the artists generally conceal environmental sounds. On the other hand, the work can be intended to be listened to privately and this has consequences for the soundscape, Michael Bull explains:

> Urban sounds that are democratically intrusive are replaced by alternative urban sound chosen by the user. This replacement changes the users' relation to the urban environment, themselves and others together with their sense of presence and time.
>
> (Bull 2000: 18)

This is far from simple. The works do not necessarily need to be made for a pair of headphones to be private. A room that is insulated from the environmental sound or in which the sounds are loud enough to mask environmental sounds will do the same. Furthermore, a work can be performed in public, recorded and then later be experienced in private.

## The Physical Properties of Sound

### *Towards a Definition of Sound as Vibrant Matter (2016)*

In 2016, Johannesburg-based artist, musician and composer João Orrechia created a series of immersive sound installations set in the old fort section of Constitution Hill. The installation comprised six rooms, each with their own sonic environment aimed at investigating the physical properties of sound in space. The sounds themselves were simple sine wave tones where, relative to the dimensions of the room, the frequency of the tone would vary. As mentioned in Chapter 4, when a sound is projected into a room, certain frequencies would reflected off the surfaces of the room and the reflected sound will superimpose onto the projected sound. This will cause some frequencies to be masked or to be amplified. A standing wave is the result of projecting a specific frequency that will, in theory, amplify itself indefinitely, an auditory equivalent of the natural resonance of the room. (Orrechia 2016: 80) Thus, each of Orrechia's rooms comprised different tones that explore, through tone generation, the "acoustic properties" (Orrechia 2016: 97) of the space. Whereas the spatial aspect is explored through a search for the resonances of the room, the temporal aspect unfolds in two ways. First, as the sound pulsates rhythmically through one's body and second, as one moves through the space. The combination of the two means that the composition unfolds through minute changes determined by the relationship between the body and the space, or what Orecchia calls the "unfolding of relational materiality of sound, space and human body". (Orrechia 2016: 94) Focussing on the temporal, the continuous projection of a pure tone makes it seem as if the sound has no beginning or end. Really, the duration of the piece is determined by how much patience the listener has to listen to a simple sine wave.

*Towards a Definition of Sound as Vibrant Matter* (2016) is an exploration into the spectrum of vibration – where frequency is tactile, corporeal and audible, raising an earlier debate on 'sound' in the absence of an experiencing subject and related phenomena that are sound-like, of which I spoke in Chapter 4. *The Table*, for example, consists of a set of speakers placed on the underside of a table which vibrate at 80Hz. The piece is experienced by placing both hands on the table as the speakers transfer the vibration through the tabletop. (Orrechia 2016: 113-114) Because Orrechia's focus is on blurring the lines between sound as audible and the imperceptible field of vibration or what he calls non-cochlear sound (Kim-Cohen, quoted in Orrechia 2016: 70) it is my opinion that this causes him to overlook the interrelated psychoacoustic factors of pitch perception and binaural hearing. *Room 5*, for example, consists of a single speaker placed in the middle of a room that sweeps back and forth between 50Hz and 700Hz. Clearly there is more at work here than merely a sound that activates a space in an interesting way – for example, the fact that a trained ear can more accurately perceive small changes in pitch, the illusion of continuity which I mentioned in Chapter 5 and the work's similarity to the psychoacoustic experiments of Diana Deutch. Probably the most important mechanisms by which auditory space, and the motion of sound in space is experienced (in the presence of two ears), yet no mention is made of the binaural mechanisms of hearing, mentioned in Chapter 4. (Orrechia 2016: Official Website)

**Figure 12: Orrechia, J. (2016) *Room 2 – The Table***

Locating *Towards a Definition of Sound as Vibrant Matter* (2016), within the context of sound installation of a similar kind, Orrechia extends upon works like La Monte Young and Marian Zazeela's *Dreamhouse* (1969) and Alvin Lucier's *I am Sitting in a Room* (1969), in his search for and experimentation with the resonant frequencies of different rooms. It must be said that I find the work strikingly similar to Michael

Brewster's *All Before* (1998). Brewster's works are some of the earliest examples of minimalist engagements with pure tones and how they behave in space and *All Before* (1998) is a compilation of these works. Speaking about *Flutter* (1979) Barry Schwabsky explains:

> The listener perceives a single complex sound, but the curious thing is that the sound changes as you move through the room; certain resonances seem to gather in one spot or another – "archipelagos of sound," as Brewster calls them. Yet the sound is everywhere in the room, giving the illusion that it does not emanate from a single source, and indeed the surfaces of the room become part of the sounding material. The stationary listener perceives a single sound, but an ambulatory listener perceives a mobile, ever-changing sequence of shifting resonances.
>
> (Schwabsky 1998: 59)

Clearly, the similarities between Orrechia and Brewster are striking. Regardless of this, *Towards a Definition of Sound as Vibrant Matter* (2016) is an important moment within the context of sound art in Johannesburg because it illustrates how sound, in its most simplified form, can draw attention to and reinvent the way we interpret contentious spaces in the city. Although Orrechia declares his lack of interest in the historical significance of Constitution Hill (Orrechia 2016: 98), the soundscape of prisons should at least be mentioned. For example, Andra McCartney has written about the Eastern State Penitentiary in the 1800s where a deliberate effort was made to isolate prisoners sonically to encourage solitude and penitence, but the practice was subsequently stopped because many of the prisoners went insane. (McCartney 2016: 162). In this sense, the acoustic properties of the prison become a carefully constructed medium to further enforce a very particular kind of punishment. It is impossible to ignore the historical significance of the space that Orrechia has chosen for his experiment, and perhaps to take an apathetic stance on the matter, at least in his writing, reveals a broader attitude towards sites that represent a traumatic past.

## *Vibrationology: Searching for Resonances in the Sonic Architecture of Matter(s) (2018)*

In 2018, Johannesburg based artist, Daniel Bruce Gray performed one of many iterations of his work entitled *Vibrationology* (2018) in the service tunnel located in the basement of the Wits School of Arts building. Various instruments of his own invention or “sound machines” (Gray 2018: 2) were scattered throughout the tunnel: a large bent sheet of metal, a series of pipes and a harp-like row of wires attached between two walls, for example. Each instrument was attached to electronic pickups that were then connected to guitar amplifiers. Gray then either continuously struck the pipes or repeatedly ran a violin bow across the surface of the large metal sheet or metal strings, causing them to vibrate. Gray’s sound machines evoke a similar search for room resonance to that of Orrechia, exploring the behaviour of sound, however, in Gray’s work, as the sound reverberates throughout the room, it causes the other instruments to self-resonate even though he is not playing them. To elaborate, unlike Orrechia, Gray’s tones are complex and coloured by the timbre of Gray’s violin bow. Here, one sound builds upon the previous sound, the present sound floating back and forth in the room awaiting the next sound in a flowing loop. But Gray’s work is also playful in how it invokes other notions of time, something he captures in phrases like “materials hold memory” (Gray 2018: 2) and “hauntedness of metal” (Gray 2018: 5). The performances are then like seances where, through sound, he attempts to extract forgotten and perhaps ancient voices from the past, locked in the material. The metal bits out of which his instruments are made are salvaged from a scrap yard, an ode to the excesses of urban living and the continuous cycle of recycling – a sheet of metal might once have been a kettle or a public telephone.

As the pieces get played over and over, they become deformed or detuned, documenting an ancient interaction. *Vibrationology* (2018) also refers to the early avant-garde and experimental composers mentioned in Chapter 3, and John Cage in particular. *First Composition (in Metal)* (1939) for example is a percussion piece that includes pieces consisting of a mixture of metal instruments and salvaged scrap metal such as four metal sheets of varying sizes. *Vibrationology* (2018) extends on this tradition within the context of Johannesburg, conjuring voices from the past hidden in discarded materials.

## Field Recording

### *LOS-JHB (2015)*

Beginning in 1966, Max Neuhaus' *Walks* series invited the viewer of art to listen to the urban environment beyond the walls of the gallery. Neuhaus would invite people to a specific location and take them on guided audio walks around New York with the word LISTEN either written on their hands or printed on the invitation. Whereas works such as Satie's *Parade* (1917) brought noises from the world into the concert hall, Neuhaus invited the listener out of the concert hall and into the street (Belgiojoso 2014: 79). The chance-like nature of urban noise and the Cagean silence unfold in a composition set to the rhythm of the listener's footfall. The soundwalk was born.

Over the coming decades there were many variations on the soundwalk, most of them including an element of field recording, either as a means of composition, such as in Hildegard Westerkamp's *Kits Beach Soundwalk* (1989), or to map space, such as in Annea Lockwood's *A Sound Map of the Hudson River* (1982).

**FIGURE 13: Suzuki, A. (2013) Oto-Date.**

The site-specificity of the work means that, in Robert Barry's words, it was "made to suit the place in which it was installed". (Barry, quoted in Kwon 2004: 12) Effectively the act of walking replaced the act of installation. The duration of *LISTEN* (1979) is also indeterminate and, as a result, one might retrace one's steps and re-experience the work. How sonic spaces change constantly and yet are permanent markers of urban acoustic identity was emphasised in works such as *LISTEN* (1979) and has extended into recent sound art works. Such is the case with Japanese artist Akio Suzuki's *Oto-Date* (1996-), which translates as 'listen point'. Suzuki travels to various urban centres around the world and invites his audience to stand at a particular point that he finds sonically interesting. The assumption is that the listener would have to walk from point to point and spend an undetermined amount of time at the listening point.

These foundational soundwalks also have contemporary permutations. This is the case with practitioners such as Nigerian artist Emeka Ogboh and Johannesburg-based artist Malose Malahlela. Ogboh's *Lagos Soundscapes* (2013) is a collection of field recordings that were made of various locations in Lagos at different times of day: the market, the bus station, a child singing in the morning, for example. What results is an auditory equivalent of the work of Lagos-based photographers such as Andrew Esiebo, and it is tempting to think of Ogboh's work as auditory photojournalism, in the sense that the recordings are documentation – long exposures of a specific location, capturing the sonic events of Lagos and attempting to be "analogues of real-world experience". (Truax 2002: 12)

It is, however, important not to overlook the nature of the auditory experience Ogboh conveys. One of the fundamental aspects of the auditory experience of Lagos is the reinforcement of a sense of community and its intimate interconnectedness to soundmaking. This is further extended in how the work is shared on the Internet. Not only are the recordings auditory windows into Lagos but they transcend time zones and merge different spatial locations. While listening to Ogboh's recordings in Berlin, Carol Magee noted this:

> Yes, this piece began with the sound of Lagos. People are talking in an open space. Car horns blare – the Doppler effect indicating their proximity to the listener/microphone, their intensity at times overpowering the voices. Then from beneath this cacophony (from Berlin) a few soft notes of piano appear – so subtle that the sounds

> of the city overpower them. They are layered beneath the sounds of Lagos, and slowly grow in loudness and frequency, as if supporting the city. As the piano music continues to intensify, it seems to rise up, becoming one with the city and cars, all the sounds moving together as if in a beautifully choreographed dance. Harmony from chaos.
>
> (Magee & Ogboh 2014: 346)

**FIGURE 14: Ogboh, A. (2013) Lagos Soundscapes**

In 2015, Ogboh exhibited his work *LOS-JHB* (2015) at Johannesburg Art Gallery. Although Ogboh often speaks of the overlapping of soundscapes within the context of JAG, it isolates them from the sounds of Johannesburg attended to by Malahlela, discussed below. *Market Symphony* (2015), for example, is a mixed media installation that plays the polyglot soundscape of a market in Lagos – but what are the similarities and differences, on an auditory level, between a market in Lagos and that of Noord Street or even the Market Square that van Onselen imagined in Chapter 5? On the one hand *Market Symphony* (2015) draws attention to the informal economies characteristic of African cities, and on the other how their sounds function to capture the ear.

## *Third Space (2013)*

Although there is a long history of field recording in South Africa, (Siopis, quoted in Engelbrecht 2010: 64) there has been a recent resurgence in Johannesburg which can be attributed to the rise of relatively inexpensive, handheld portable digital recorders.

In the past, field recording was an ethnomusicological endeavour where the indigenous music of South Africa was documented through the ears of white male listeners, most notably Hugh Tracey. (Cloete 2020: 49-57)

During 2013 Johannesburg based artist Malose Malahlela recorded a series of sound walks entitled *Third Space* (2013) and *Audio Walk with Ra and Kagiso*. Both recordings are guided tours of the inner city, Joubert Park, Yoeville and Hillbrow.

The unfolding of the soundscape as a product of walking can be likened to the needle of a record player: as the needle runs through the groove of the record so too does Malahlela walk through the city; he takes the needle for a walk. His work for the Sound Development City entitled *Third Space* (2013) can thus be heard in relation to a tradition of Hip Hop disc jockeys beginning with DJ Kool Herc and Afrika Bambaata. But instead of mixing two records and cutting between the two or layering one on top of the other to compose a new soundscape, Malahlela layers one soundwalk on top of another.

Malahlela also incorporates narrative, poetry and background music played on a boombox (James 2018: 19-22), which not only situates the recordings within the oral tradition of the city past and present, but also forms new trajectories of interpretation that deviate from the trajectory of the walk itself. This is clear in both *Third Space* (2013) and a later work entitled *Audio Walk with Ra and Kagiso* (2013). The transcription from *Third Space* (2013) below captures the essence of Malahlela's approach to sound walks evident in both works.

> Welcome! Welcome to Johannesburg, Johustleburg as many call it. The City of Gold, E-goli. My Name is Bheki Dube and I'll be taking you through the streets of Johannesburg. We're going to be walking now venturing off into the bustling streets of Johannesburg, past Noord taxi rank to the famous Joubert Park, as well as the Johannesburg Art Gallery (JAG). We're going to be going through levels of crazy emotions from sounds to even quietness, but it's all about experiencing and engaging with the city as locals do. Follow me, as I become your lead in this notorious city. We are buying some stuff from the street traders, engaging with them, asking them, talking to them and touching on a few historical buildings that we're seeing on the streets. We are on the corner of Twist and De Villiers Street walking all the way straight on Twist Street. You can see, to my right hand side we've got some Pakistanis selling some lovely clothing and electronics. On the left, into Noord Street off Twist

> Street there's a lot of markets that are happening here, and sometimes I tend to raise my voice because of all the ambiences we find on the streets. To my left is Chicken Licken and to my right I've got market stalls. Lovely music from all around the world and this is the heartbeat of Johannesburg.
>
> Walking now we're going to walk about 50 steps through the market itself. [...] you can get anything here, from sandals to shades, gold, the latest cellphones...whatever...fresh fruits, and even ice. So you hear now we're getting different sound bits of some lovely music from up North Africa, all different cosmopolitan synergies within the space. Everyone here is here for hustle that's what Joburg's for, people come here between 9 AM and 5 PM, they dig as much as they can, they hustle as much. By 5-6 PM the streets become very quiet. It is the principle of Johannesburg. People came here just mining and what has been passed on through generations, is not mining anymore but other forms of trade. Now we've reached the end of the market and it seems to quiet down a bit.
>
> (Sound Development City: 2013)

This description of the Johannesburg, much like a tour guide, is also a key part of *Audio Walk with Ra and Kagiso* but it is less literal and more focused on the interpretation of the historical, social and cultural significance of particular spaces in Johannesburg, with the narrators oscillating between describing what they see and expressing how they feel. Here, the spaces are not merely spaces but are symbols for subjective experience that become code words for new interpretation between one site and the next, as facilitated by the soundwalk. (Audio Walk with Ra & Kagiso: 2013) Malahlela's recordings are important because they are an auditory testimonial of the city through music, spoken word and memories from the viewpoint of young black Johannesburgers in post-apartheid South Africa.

## Voice

### *Echolalias (2016)*

In previous examples, I discussed sound works that make use of the voice in its spoken form. There are musical qualities inherent to everyday speech that function to convey meaning beyond semantics, within a particular context such as intonation and emotional expression. (Ostwald 1963: 51) *Echolalias* (2016) by Bettina Malcomess is an exploration of the gradual disintegration of the intelligibility of the voice into a realm where it becomes purely sound. Working with several reel-to-reel tape recordings of her own voice, the artist achieves this disintegration in two ways. First, she uses tape loops. The more the listener hears the loop, the stranger her voice becomes. This is a phenomenon known as semantic satiation and similar to works such as Robert Ashley's *She Was A Visitor* (1979). Second, the artist uses more than one loop and as they play simultaneously, the slight difference in their playback speed causes them to go in and out of phase with each other. Thus, when the loops are synchronised, the words are intelligible, but as they slowly lose their synchronicity, the words sound more and more foreign.

Of course, *Echolalias* (2016) is significant in terms of sound art in Johannesburg because Malcomess is one of the few artists using old tape players and reinvigorating the Schaefferian conversation about acousmatic listening, mentioned in Chapter 3, but the work also asks important questions about sound art and documentation. The work consists of an ensemble of reel-to-reel tape players onto which tape loops are strung. The switches click the players on, and a barely audible electronic hum is emitted.

**FIGURE 15: Malcomess, B. Performance with Tape Recorders. (no date)**

The loud clunky dial sets one loop in motion and then another, and another. As the tape repeatedly runs through the noisy whirring mechanisms of the player and over the tape head, the delicate loop gradually disintegrates. However, the sound of the loop itself persists long after the tape has disintegrated, and the loops linger in only in memory, these memories also fade eventually. By persisting in memory, Malcomess' work extends the 'foreknowing' of sound beyond the immediate moment; creates so-called earworms. (Malcomess, no date: Anne Historical)

## *Slaap my kindjie, slaap sag (2013)*

> *Slaap my kindjie slaap sag* explores the voice and the use of song within my personal context and has a significant impact on the re-evaluation of my past and current Afrikaner identity.
>
> (Theart 2013: 84)

Song is a blend of poetic and expressive devices such as meter, rhyme and emotional expression, realised through the musical arrangement of varying pitches and rhythms into a melody. Of course, this is an oversimplification, but it suffices to demonstrate that song is an intersection between music and spoken word.

The emotive yet non-linguistic vocal communication between mothers and infants is well documented (Geltner 2013:17). Singing a lullaby reinforces social bonds between mother and child, intending to soothe and reassure a child to sleep. In 2013, Johannesburg based artist Pauline Theart installed her work entitled *Slaap my kindjie, slaap sag* (2013), a site-specific sound work located at the Children's Memorial Institute in Braamfontein. The work consisted of a four-channel loop of her singing a traditional Afrikaans lullaby of the same name, the song itself a contrafactum of Johannes Brahms, *Wiegenlied*.

Listeners were asked to stay seated for the duration of the piece and contemplate not only the loss of the fallen soldiers for which the memorial was constructed, but also the loss of Theart's Afrikaans heritage. This rumination is further reinforced because the piece plays repeatedly and becomes almost like a chant. *Slaap my kindjie, slaap sag* (2013) is not only important because it is an investigation of the use of song in sound art, where examples are few, but also asserts something more powerful about her identity as an Afrikaans woman in Johannesburg. Cathy Lane describes the pertinence of this:

> Women sound artists use voices, their own and others,' in ways that subvert commonly held historic, sociocultural prejudices against the existence of women's voices in public spaces. Sound art, perhaps because of its relatively emergent status as a genre or because of its essentially ethereal, disembodied, nonmaterial nature, provides a space in which women feel that they can be and have a right to be

> heard. The recorded speaking voice is decoupled from the physical body and becomes "liberated," allowing women sound artists to explore their own voices, both to critique existing political and cultural realities and to create visions of new sonic utopias.
> (Lane 2016: 109)

By assuming a maternal role, *Slaap my kindjie, slaap sag* (2013) then stresses the subversion of gender roles by using a lullaby to ask politically charged questions about race, identity and the suppression of Afrikaans culture in post-Apartheid South Africa. *Slaap my kindjie, slaap sag* (2013), through Theart's intervention, becomes more like a song of protest than a lullaby.

## Musical Performance

### *For the pianist's eyes only (2010)* and *Vehicle (2018)*

The Centre for the Less Good Idea (with the name perhaps being a play on the famous Goodman Gallery in Johannesburg and Cape Town) concentrates on the exploratory ethos of interdisciplinary work in attempting to create a kind of cult of avant-gardism in Johannesburg. The suggestion is that the artists who are to define this cutting edge live in the Maboneng Precinct or some similar part of 'old' Johannesburg. Despite this, the thematic seasons around which they organise the projects are usually headed by, or involve, more established artistic practitioners. There is a broad range of work resulting from this workshop-like environment. Many of these have a sonic element but none of them deal particularly with the sound of Johannesburg in relation to the experience of space and time itself.

Season four featured Gerhard Marx's *Vehicle* and Jill Richards' *For the pianist's eyes only* (2010). *For the pianist's eyes only* (2010) is a piano piece which begins with Richards playing a short musical phrase. She pauses and says, "Something seems to be wrong here," an apt statement for the iconoclastic gesture that is about to occur. She then lifts the lid of the piano to inspect it. Then takes a piece of the piano and throws it on the flour and plays another phrase. This continues until very little of the piano remains. Where does the piano begin and where does it end? Introducing the sorites paradox, Mark Heller asks a similar question:

> It is supposedly true of a heap, any heap, that there is some portion of the heap that is small enough that the heap can survive the loss of that portion. It is also true that any heap that there is some portion that is big enough that the heap cannot survive the loss of that portion.
>
> (Heller 1990: 47)

*For the pianist's eyes only* (2010) asks: at what point is it no longer a piano? When it is out of tune? When it can no longer play all of its keys? When it is a heap of parts? The way in which the destruction of the piano is audible is similar to Jean Tinguely's *Homage To New York* (1960), a Rube Goldberg-like kinetic sculpture in which various found objects are set into motion, the motion itself then resulting in the falling apart of the sculpture. The gradual disintegration of *For the pianist's eyes only* (2010) is also similar in form to Haydn's *Symphony No. 45 (Farewell)*, in which musicians leave the stage one by one. The iconoclastic edge is also fairly common in terms of works featuring the piano as an instrument, such as Al Hanson's *Yoko Ono Piano Drop* (1970), a happening which calls for a piano to be dropped from the roof of a gallery or museum.

**FIGURE 16: Marx, G. Vehicle (2018)**

*Vehicle* (2018) is a violin piece in which violin strings are attached to fragments of a dismantled motorcar in a way that makes the audience imagine what it might be like to hear George Braque's *Violin and Newspaper* (1912) in a sculpturesque form similar to the reconstructed instruments of Trimpin. Much of Marx's work is so deeply entrenched in map making and cartography, perhaps *Vehicle* (2018) is pointing a fracturing of urban experience in Johannesburg, a city largely navigated by car. Even though the resonating body for the reconstructed violin is the broken body parts of an old car, and a car refers to traffic and roadways, there is little that connects *Vehicle*

(2018) to what might be a sound map of Johannesburg. (The Centre for the Less Good Idea, no date: Official Website)

**FIGURE 17: Lockwood, A. Piano Drowning. (1972)**

*For the pianist's eyes only* (2010), too, conceals the sound of the environment, but this is familiar to the concert hall. It also has a fixed duration. The keys gradually disappear under the pianist's fingers and when the piano ceases to play, the audience applauds and Richards takes a bow, another convention of the concert hall. The work is less about the environment than it is about the subversion of these conventions, but it does point to the potential of what a work like *For the pianist's eyes only* (2010) could reveal about the sounds of the environment. Lockwood's *Piano Drowning* (1972) (Figure 16) illustrates the point:

> Find a shallow pond with a clay/other hard bed in an isolated place. Slide upright piano into position vertically, just off-shore.
>
> Anchor the piano against storms, e.g. by rope to strong stakes. Take a photograph and play it monthly, as it slowly sinks.
>
> (Lockwood 1972: Piano Transplants)

Even though there was potential for both *Vehicle* (2018) and *For the pianist's eyes only* (2010) to, at the very least, take note of the sound of Johannesburg and the spaces which this sound evokes, sound in these works is less important than the object itself. *Vehicle* (2018) is an attempt to transport the viewer or listener into a world where the eye and ear collide. Whereas Marx puts broken objects back together in a new configuration, Richards takes the object apart, but still in a way that refers to the object itself as well as the sound it makes as it gets dismantled.

Given the current interdisciplinary focus of research centred around making, it is only natural that there would be more of an auditory component to the work made at The Centre for the Less Good Idea. The trouble is perhaps related to how the centre refers to itself as an "incubator space". Although the term appears to be quite popular, particularly in political circles, when it comes to interdisciplinary art making it seems counterintuitive. Why would artists need protection from their immediate environment, and why would they need to be isolated from it? This becomes even more glaring when one thinks about the location of Maboneng within the inner city. If the Centre could see itself as a series of workshops rather than an incubator, then perhaps the works in sound would become more engaged with the sound world in which they are immediately located.

Clearly it is ironic to locate the Centre in Maboneng and yet insulate its practice from the immediate environment. This is certainly clear in *For the pianist's eyes only* (2010) and *Vehicle* (2018), particularly in relation to the sound of the city. Maboneng itself is a marker of the reinvigoration of urban culture as mediated by the city centre; or so it appears. To isolate the work from the sound world in which it is located raises complex questions about the social antagonism inherent in places like Maboneng that are beyond the immediate purpose of this chapter. Performing the works outdoors would have created opportunities to explore the sounds of the immediate environment.

## *Hlabelela: It's a New Mourning Nkush (2016)*

Since Brian Eno, Laurie Anderson and many others, it has become common for artists to make music, release albums and perform beyond the walls of the gallery space. Within the context of the emergence of sound art, it also became more prevalent for bands to perform in gallery space. Similarly, in Johannesburg, the gallery has become a stage or a dance floor in recent times. It is unclear how these works are to be read, and perhaps this is their strength. Because of the gallery context, the work locates itself in relation to the tradition of performance art. But these are musicians and disc jockeys first and foremost, before they are performance artists who have been displaced from their conventional frameworks of performance. This raises interesting questions about the gallery itself, and what kind of new audiences are created by these performances, more so than it does about the musician or the disc jockey.

The Brother Moves On is a band based in Johannesburg and surrounds, and much of their work is collaborative. Their performance at The Goodman Gallery entitled *Hlabelela: It's a New Mourning Nkush* (2016) could be understood within the context of bands in the gallery. Frontman Siyabonga Mthembu's voice is not smooth and soulful; it is grimy, bold and sumptuous, matched with lyrics that range from the playful to the outright riotous and includes everything in between. Stylistically, the intonations of Mthembu's voice are characterised by prolonged phonemes and accentuated percussive consonants reminiscent of a preacher, a politician or an auctioneer. By referring to this vocal style, the performances present themselves as ceremonious. *Hlabelela: It's a New Mourning Nkush* (2016) consisted of a performance in which the gallery was divided into numerous spaces, with the audience being led by Mthembu from one space to the next in what resulted as an expanded view of the band. Various objects, spray painted in gold, were scattered throughout the space such as an outside toilet made of corrugated iron, a bull's skull and a broken pair of headphones.

The audience takes part as a group that finds themselves somewhere between a congregation and an assembly of rioters, and the music becomes ritualised. Because this is a band, one has to assume that the performances are informed by some form of commercial interest, with the amplification creating the compulsion to purchase. In this case the listener is buying into the idea of South African freedom and libertarianism. What is interesting about The Brother Moves On and the performances at The Goodman Gallery is that the typical corporate interests that usually back bands are replaced by the ideological values associated with the gallery. Whether The Brother Moves On is aware of this, or whether the performances question the institutional structures of the gallery is debatable. (The Brother Moves On, no date: Official Website)

Although these performances are sonorously rich in their musical intention, the question of sound in space does not seem important to the performers. It is impossible to think of the performances as singing sculptures, sound installations or sound art. The performances are rooted in music and the gallery space seems incidental. One cannot help but think of this kind of work in relation to the countless African artefacts collected by museums for their aesthetic value, at the expense of understanding what the objects are used for or the context from which they emerged. The Brother Moves On is, however, not only a band; it also represents a spirit. It is comparable to Walter Battiss and Norman Catherine's Fook Island in its nomadic and anarchic form. Battiss invented Fook Island after travelling to remote parts of the world and particularly the Pacific Islands. Upon his return, yearning for an escape from the real world, he created the island, complete with its own currency and community of citizens. (Battiss, no date: Fook Island) Battiss' work and Fook Island was recently the subject of a retrospective exhibition and accompanying publication held at Wits Art Museum entitled *I Invent Myself* (2016). Similarly, *Hlabelela: It's a New Mourning Nkush* confronts the viewer with fragments of time and turbulent spaces, a fictional map of deep-time, based on ancestry and anecdote. However, one interprets the performances by The Brother Moves On at The Goodman Gallery, the work speaks both to the receptivity of the gallery to musical performances and the opportunism of the musician.

*Hlabelela: It's a New Mourning Nkush* (2016), *For the pianist's eyes only* (2010) and *Vehicle* (2018) are all influential to sound art in Johannesburg because they not only dissect the vernacular of music but also reject conventional modes of musical reception. How these works reflect the rich history of music in Johannesburg and why they call it into question, as I have already mentioned, is grounds for further scholarship. What is clear is that they signal and important milestone for both music and sound art in Johannesburg.

To conclude, I have provided a method for analysing sound artworks based on phenomenological analysis. I attended to two preliminary questions namely documentation and description. Documenting sound can function as the afterlife of the work but, because of the nature of recording, can often become the work itself. Description should draw on many disciplines, but it is important to be aware of conflicting terminology. When describing an encounter with a sound artwork, it is useful to speak of its observable features and I proposed a series of questions. Because there is a common difficulty in describing the auditory experience, I summarized Ostwald's text on making statements about sound, and pointed out the significance of the auditory context of sound works and their placement within the various acoustic zones of Johannesburg.

I then provided a survey of works in sound and divided them into four categories, assessing their significance to the story of sound art in Johannesburg. Orrechia's work showed how sound art that is generally focussed on the physical properties of sound in space, can reinvent how we perceive historically contested spaces, or with Gray, how these experiments can be purely playful. Ogboh and Malahlela's field recordings and sound walks questioned the impact of globalisation on local identity within the context of an increasingly networked world. Malcomess revealed the potential for the purely sonorous qualities of the voice, and Theart called attention to the power of the woman's voice as a medium of protest. Lastly, Richards, Marx and The Brother Moves On went beyond music to destabilise old institutions of listening, making use of the art space to invent alternative forms of musical reception.

It has been useful to divide works into categories because it has helped to identify trends, although there are many points of overlap. For example, *Vehicle* (2018) and *Vibrationology* (2018) both made use of a violin bow, Orrechia, Theart and Richards are all trained musicians, and Malcomess and Gray could both be spoken of in terms of performance art. What has become clear since the writing of my Master's dissertation is that works have dealt more explicitly with sound, as opposed to sound acting to support the visual. This being said, the instances of works in sound are still not as numerous as one would hope. What has become clear, however, is that, except for field recording, none of the works have engaged in meaningful ways with the immediate auditory environment in which they are located, as Idhe suggests. Part of the purpose of this paper is to act as a foundational text for sound artists in Johannesburg. For this reason, in the next section I would like to reflect on the roots of sound art focusing specifically on the experience of space and time that might suggest ways to more directly engage with the sounds of Johannesburg.

## Sound Art and the Experience of Space and Time Revisited

Thus far in this chapter, the analysis of selected sound art works produced in Johannesburg was followed by a discussion of applied soundscape studies, perhaps better called sound field studies, and how these have been used in some urban space as well as in broader settings. The concluding section will offer a short overview of examples from the perspective of sound art as a means of investigating space and time. In many ways this is an act of remembering the roots of sound art in relation to its origins in site-specific practice. Once again, the number of sound art practices in Johannesburg that take this mode of production as their starting point are few. It is for this reason that the examples that I discuss below are intended to initiate a thought process on how sound art could potentially be applied in the context of Johannesburg as a means of experiencing space and time. The basis for this will be provided by revisiting the principles established by works in isolated spaces, in order to suggest a series of starting points from which the broader sonic environment could be invoked.

In art historical terms, there are two important moments that initiated the use of sound in space and time. The first is Max Neuhaus' *Listen* (1966-), and the second La Monte Young and Marian Zazeela's *Dreamhouse* (1963). The significant difference between the two pieces lies in the choice of space. Neither of the works was located within the gallery but whereas *Listen* was an expedition into the sound world of outdoor space and asked the listener to hear real-world sounds differently, *Dreamhouse* was set in a contained space and reconstructed the hum inherent to the city against the backdrop of cascading ambient magenta light. (Martens 1988: 28-29) Whereas the duration of

*Listen* is determined by how the listener wanders through urban space and has a starting point and an endpoint (Belgiojoso 2014: 79), the beginning and end of *Dreamhouse* seems indeterminable – as the listener approaches the work, a faint sound draws them into the room, and as they move away, the sound dissipates. It can be argued that many site-specific sound artworks were inspired by these two examples and how they activate space and time.

In Chapter 3, I mentioned Alvin Lucier's *I am Sitting in a Room* (1969). The work unfolds by Lucier recording the first time that he reads the phrase; at the same time that the recording is being played back the second recording takes place and is also played back while the third recording is made. This process is repeated another 32 times. This is similar in structure to a fugue and similar in form to a responsorial; but is for a solo performer. The piece is self-explanatory and a minimalistic gesture towards how sound is used to describe space.

What the audience hears is the surfaces of the wall, roof and floor, the materials that these are made of, Lucier's body in the room, the temperature of the room and so forth. Each time the passage is replayed, the past is superimposed onto the present as the resonance of the room becomes more amplified. (Lucier 2012: 88-91) Lucier went on to produce many more works that investigated sound in space such as *Vespers* (1969), in which a group of performers were blindfolded. Using echo-location devices, they navigated their environment by means of the sound that returns to them.

The movement of sound in rooms and how the body moves in relation to the patterns or paths the sound follows has been the focus of Bernhard Leitner's work. The works consist of a series of speakers where a sound travels from one speaker to the next in a way that creates the illusion that the sound is moving either along a path, such as in *Sound Lines Sculpture* (1972), or throughout the entire room, such as in *Soundcube* (1969) (Figure:18) and the subsequent variations thereof in *Sound Space* (1983-) a permanent sound installation located at the Technical University in Berlin. (Stjerna 2013: 4-5) Furthermore, Leitner's work is an exploration of interaural time difference through which the two ears track the movement of a sound from one position to the next. (Leitner, no date: Official Website)

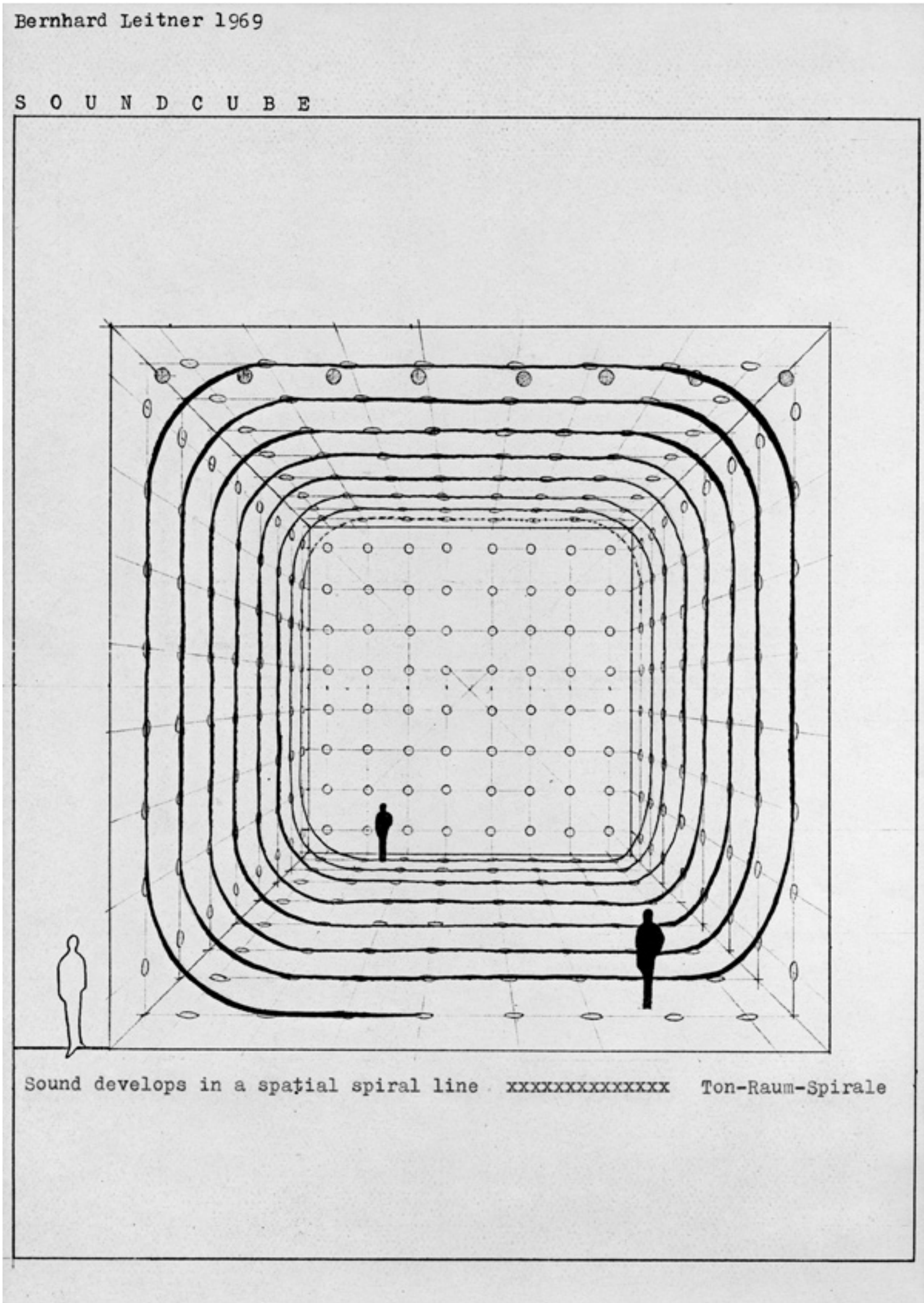



**FIGURE 18: Leitner, B. Soundcube. (1969)**

If Leitner's sound works show the variety of ways in which sound can move through a cube and how the listener's ears follow these sounds, then Liz Phillips' work does the opposite. Her sound works are triggered by the movement of the body in relation to a series of sensors and are activated by motion and proximity to the sensors. This is the case in early work such as *Sunspots* (1982), *Syzygy* (1983) and *Echo Evolution* (2002). *Sunspots* is based on the principle of a Theremin which is tuned to the dimensions of the room in which it is located. (Phillips 2009: 57-62)

As the viewers enter the room or move around it, their movements and proximity to a copper coil cause sounds to play. Similarly, *Syzygy* is a work emitting ultrasonic frequencies that create a sonar image of the space and the people in it. It tracks their movements and, based on the ultrasonic image that the work creates, a soundscape radiates. *Echo Evolution* is another piece that uses sonar but in this case the work also radiates light. How accurate these pieces are in translating small movements or small objects into sound we cannot be sure of. Nevertheless, the point remains that Phillips' interactive sound installations are important in demonstrating how the body can become an instrument of the soundscape. Importantly, the movements that activate the sound can be fast or slow and the body's proximity to the work can be near or far. These variables translate into either high- or low-pitched sounds that make the immediacy of the moment audible through gesture. (Phillips, no date: Official Website)

Both Leitner and Phillips are concerned with the nature of sound in an interior space and the relationship that the body has to the sound as experienced in the space. The work of Maryanne Amacher is also about the space and time, but her approach is entirely different. In Amacher's *Living Sound: Music for Sound Joined Rooms* (1980) the work is performed by using the structural sound of the building and creates standing waves according to the dimensions of the rooms. Speakers are placed in various locations around the space and visitors are encouraged to walk around as is the case with Leitner and Phillips, but here it is a live performance. To find the sounds that are inherent to the building itself, amplifying the structure-borne sound of walls, the creaking floorboards as someone walks over them, the opening and closing of a door, the plumbing, the air conditioner, the buzzing of a fluorescent light or a branch brushing against a window, is a very perceptive and meticulous take on soundscape in relation to architecture. (Amacher 2017: 119-122) Amacher's work is similar to the work of Leitner and Phillips in how the movement of the body in relation to the sound foregrounds the experience of time and space. However, the experience of time in Amacher's work emerges by moving from one room to the next. This idea of building-as-instrument was later picked up by David Byrne in *Playing a Building*, in which piano keys are connected to a variety of mechanical devices that would strike a railing, knock on a wooden staircase, etc. (LaBelle 2006: 170)

When sound artists exit the gallery and make outdoor spaces their subject, the work becomes associated with related practices such as land art and site-specific art, and the relationship between site and sound often turns out to be reciprocal. One cannot be sure whether the spaces that land artist use are chosen with the soundscape of the space in mind, or whether sound artists choose their sites as a means of intervening in the landscape in non-tangible ways. What is evident and important to mention at this junction, is how related practices are continuously cross-pollinating. Perhaps this is the strength of sound work: it assimilates, and it is a very immediate way of working.

This cross-pollination can be illustrated by looking at three examples: Bruce Nauman's *Stamping in the Studio* (1968), Richard Long's *A Line Made by Walking* (1967) and a work I mentioned earlier by Max Neuhaus', *LISTEN* (1976). The starting point of all three works is a fundamental human condition, our ability to walk upright. Nevertheless, elements of each work in the next are evident. Nauman's work is a video piece of a performance in his studio. He marks out a square on the floor and stomps his feet within the boundaries of the square. (Van Bruggen 2002: 59) Long's work is a line drawn in the grass made by walking up and down until the grass clears a path; and Neuhaus' work is a pathway through the city where we listen to the music of urban space as marked by the rhythm of our footsteps. Notably, all three works are about that moment when our feet touch the ground. We can appreciate Nauman's work for how this moment becomes an expression of emotion through the body, with the aggravation communicated by the noise of stomping embedded in the sound. Long's work is the trace of repeated footsteps that begin with the rustling of his boots through long grass – a sound that is transformed over time into the thumping of his footsteps on compacted soil. (Strandhagen 2014: 185-187) Neuhaus' work, similarly, raises a question about what kind of emotional expression underpins one's footsteps in the rhythm of walking and listening. It also evokes images of urban walking and routine. We walk up and down the same street every day – but do we listen?

There are many ways in which sound has been used to intervene in the landscape but within the context of this overview, I will mention only a few. The first example is the work of Douglas Hollis. Hollis' sculptures and installations take their inspiration in part from the Aeolian harp, a string instrument invented by the Greeks that is played when the wind brushes over the strings. The work can also be contextualised within a broader tradition of kinetic sculpture and work by artists such as Alexander Calder. These influences result in outdoor kinetic sculpture that is set in motion by wind and water with the aim of making sound. Hollis' sound sculptures are the auditory equivalent of stained-glass windows, intervening in the path between the naturally occurring conditions of our environment and our senses. The sculptures take a variety of forms, some of them using wind, such as *High-Back Windharp Chairs* (1982), in which four chairs are placed on top of a hill overlooking the landscape of Santa Theresa, California. The backs of the chairs are extended and strung with strings that produce sound when the wind blows over the hill. Other works use water, as in *Tidal Park* (1988), a spiral-shaped amphitheatre that resembles both a cochlea and a seashell, the spiral ascending in steps to create a tidal clock. As the audience hears the waves crashing in the background and as water ebbs and flows through the tidal park, what they are reminded of is the gravitational force of the moon set to the rhythm of sunrise and sunset. (Hollis, no date: Official Website) *Tidal Park* is a take on *Wave Organ* (1986), an earlier work by another prolific sound sculptor, Peter Richards, which was made in San Francisco Bay in collaboration with stone mason George Gonzalez. There have been many variations since but unfortunately, we do not have something similar along the South African coast.


**FIGURE 19: Richard, P. Wind Wall. (2006)**

There are many similarities between the work of Douglas Hollis and Peter Richards. The difference is in how Peter Richards often uses the absence of sound to suggest the potential for sound or refer to sonic qualities. *Wind Wall* (2006) (Figure: 19), for example, is a kinetic sculpture located on the façade of the LIGO Science Centre in Livingston, Louisiana. The piece consists of a series of vertical beams that run along the entire façade. The middle of each beam pivots slightly on a central axis so that when the wind blows, the beams become a fingerprint of the wind's wave-like motion.

If *Wind Wall* refers to a visual representation of sound, then *Pole Field* (1991) in Byxbee Landfill Park is about the potential for sound. The work consists of a series of telephone poles located on top of an old landfill site, the intention being for the birds to use the top of the poles to perch upon. Initially, when I think of the work in relation to sound, I think of birdsong. But the piece is also about the ways in which the birds will orientate themselves in an upwind direction, becoming living versions of the rooster wind vane. One can imagine that there is a real need at a landfill site to be conscious of wind direction, but the piece also refers to the bird population at landfill sites and the new ecosystems that are emerging as a result of human waste. The birdsong of *Pole Field*, then, draws attention to the environmental impact of densely populated areas in the context of the things we throw away and forget about. (Richards, no date: Official Website)

The potential for sound in relation to the orchestrated mechanics of the landscape is not exclusive to wind and water, as illustrated by Walter De Maria's *The Lightning Field* (1977) (Figure 20). The field consists of 400 stainless steel lightning conductors placed in a grid-like fashion within a 1 mile by 1-kilometre rectangle situated in Carlton County, New Mexico. The grid is much like a blank page of sheet music, each lightning conductor representing a ghost note as it gets struck, the sound reverberating through the body of the listener. The lightning field is an ode to the percussion of the sky that is, for the most part, clear and silent but could also potentially break out into a furious improvised solo or ensemble. (Baker 2008: 7)

While De Maria's *The Lightning Field* depends on the large-scale open-air space in which it is situated, some sound works engage with smaller, intimate and often hidden spaces, particularly when they are located in urban environments where our instinctive idea of space suggests confinement and compartmentalisation. Two facets of urban space are worth emphasising: the scaled down dimension of urban space and the hidden dimension of urban sounds. In the first instance works such as Bill Fontana's *Acoustical Visions of Venice* (1999) and Michael Brewster's installation *Concrete Two-Tone* (1978) are significant. The second instance is illustrated by Jacob Kirkegaard's *Broadway* (2007) and *Invisible City* (2017), Christina Kubisch's *Electrical Walks* (2006) and Brian House's *Acid Love* (2018)

**FIGURE 20: De Maria, W. The Lightning Field (1977)**

In relation to vision, the urban landscape is the disruption of one's line of sight: there is no horizon in the city, only a façade, a skyline or a one-point perspective where the lines never completely converge. *Acoustical Visions of Venice* (1999) is an auditory expression of this and is based on the idea of hearing as far as one sees. Fontana placed microphones in 12 strategic locations around Venice, which streamed live sound to a central point at the Punta Della Dogma. When listening to the work, it is worth thinking of the moments of silence as the eye looks far into the distance and the ear is searching for the horizon. When one hears sound, even a single sound like this, one thinks of it as a disruption, an obstacle in the way of long-distance listening. By projecting one's ear into the distance, that which is located in front of the horizon becomes intensified and the actual sound is being inadvertently contemplated. (Wilson 2002: 418-419)

If *Acoustical Visions of Venice* activates the ear searching for the horizon, then *Concrete Two-Tone* seeks to reimagine what is already there. The work was situated in a soon-to-be highway tunnel in the Netherlands and, like in many of Brewster's sound works, two pure tones were played into the tunnel. The same frequency was played but was slightly mismatched to create a binaural beating in the tunnel. As a result, and depending on the ear's location in the tunnel, pulses of sound would change. The importance of the work is that the choice of space is seemingly arbitrary. Within the continual language of destruction and construction of the city, Brewster finds a space and through a very subtle intervention in sound, places it in italics - *this* space. (LaBelle 2006: 167) It leads one to think differently about the form of the built environment and the possibility that we might be inadvertently creating spaces that are acoustically interesting. (Brewster, no date: Official Website)

Brewster is asking us to reimagine the forgotten urban space that we use every day by searching for the sounds of space with new ears. There certainly is a hidden world of sound that can be found in everyday urban spaces we encounter, and this is the sound world that Jacob Kirkegaard aims to reveal. In *Broadway* (2007) the steel columns of the gallery housing The Swiss Institute were recorded with accelerometers. The columns are, of course, wedged deeply into the ground, but the highly sensitive accelerometers could pick up the subtle vibrations caused by street activity and the subway. The vibrations from the recordings were then played back through the columns using 60 exciters – and thus the columns became microphones and speakers that revealed the inherent vibration of Broadway. The more recent *Invisible City* (2017) documents the unheard sounds of Copenhagen, such as the sound of the police court, Post-Nord's night-time letter sorting, the underwater rivers and canals and the electromechanical working of the city clock. *Invisible City* is also about unheard sounds but instead of listening to what is beneath or feet, we listen when nobody else is, spying on the city and revealing the clandestine sounds of Copenhagen. (Kirkegaard, no date: Official Website)

The way in which Kirkegaard reveals the vibratory essence of the streets in *roadway* is similar to Christina Kubisch's *Electrical Walks* (2006) in how it seeks to listen to that which cannot be heard. However, instead of making the underlying vibrations inherent to urban space audible, Kubisch makes audible the realm of electromagnetic fields. (McCartney 2014: 226) One is given a set of magnetic headphones and encouraged to walk through the city, listening to the electromagnetic fields transmitted into everyday environments by everyday objects such as lighting systems, surveillance systems, various cables, WIFI networks and so forth. *Electrical Walks* (2006) makes audible the electronic aura of the city, its pulse. Walking through urban space is like swimming a charged ocean of communication, the city's buzz, and Kubisch is its translator. (Kubisch, no date: Official Website)

What becomes evident in the work of both Kirkegaard and Kubisch is an exploration and reconfiguring of sound's circuitry. This is not simply a process of recording and playback or the projection of sound into space. The steps that sound takes from being sensed, whether by a microphone, accelerometer or an electromagnet, are extended and reconfigured in different ways. This is a question about what unexplored and unexpected sources of sound might be and about what else can be used as their resonator. As a result, the work avoids conventional sound media like the microphone, the amplifier and the speaker. Our final example, the work of Brian House, illustrates this.

House's work often makes real-time data audible. *Animas* (2017), for example, is based on the contamination of the Animas River in Southwestern Colorado in 2015. House installed sensors into the water that provided data not only about the flow of the river but also about its clarity and the amount of dissolved heavy metals in the water. Three rectangular sheets of metal fitted in the gallery were connected to transducers that made the sheets vibrate in response to the real-time data that was sent to them by the sensors located in the river. You were hearing the river's flow, toxicity and clarity. More recently, *Acid Love* (2018) was a research project in collaboration with The Centre in Water Research and Development at the University of the Witwatersrand that sought to shed light on acid mine drainage in Johannesburg. As a consequence of the activities of the mining industry in Johannesburg, much of the surrounding water has become contaminated. House collected samples from water sources and connected them to a circuit that would make audible their conductivity and therefore the acidity and amount of heavy metals in the water. Although House's work is important in terms of how he translates data into sound, there is little that suggests an exploration of the sound as means of exploring space as a medium as well as highlighting the impact that Johannesburg's past has on the present in terms of the environmental impact of mining. (House, no date: Official Website)

**FIGURE 21: House, B. *Acid Love* (2018)**

In this final section I have discussed sound and the experience of space itself in a non-chronological fashion and paid little attention to the art historical traditions that the works might be situated in. By discussing a number of examples, I have hopefully demonstrated the potential for sound art to be a means of exploring space, whether it be the space created by a room, open-air outdoor space or the outdoor and hidden spaces of the city. What revealed itself are the interesting new ways in which the circuitries of sound are being reconfigured, allowing us to broaden our range of thinking about sound as a medium.

In this chapter, I have recommended a methodology for speaking about sound works, provide a survey of works that are significant to the emergence of sound art in Johannesburg and reflected on the roots of sound art, focusing on the experience of space and time. By introducing these works in both the first and the second section, the primary objective has been to evoke the potential for sound art in Johannesburg. There are certainly questions about urban auditory experience that sound art is well-equipped to address and I would like to suggest that returning to the notion of the soundscape is an ideal starting point for future scholars. How sound art can feature more prominently to engage the sounds that we share, remains an open question.

# CONCLUSION

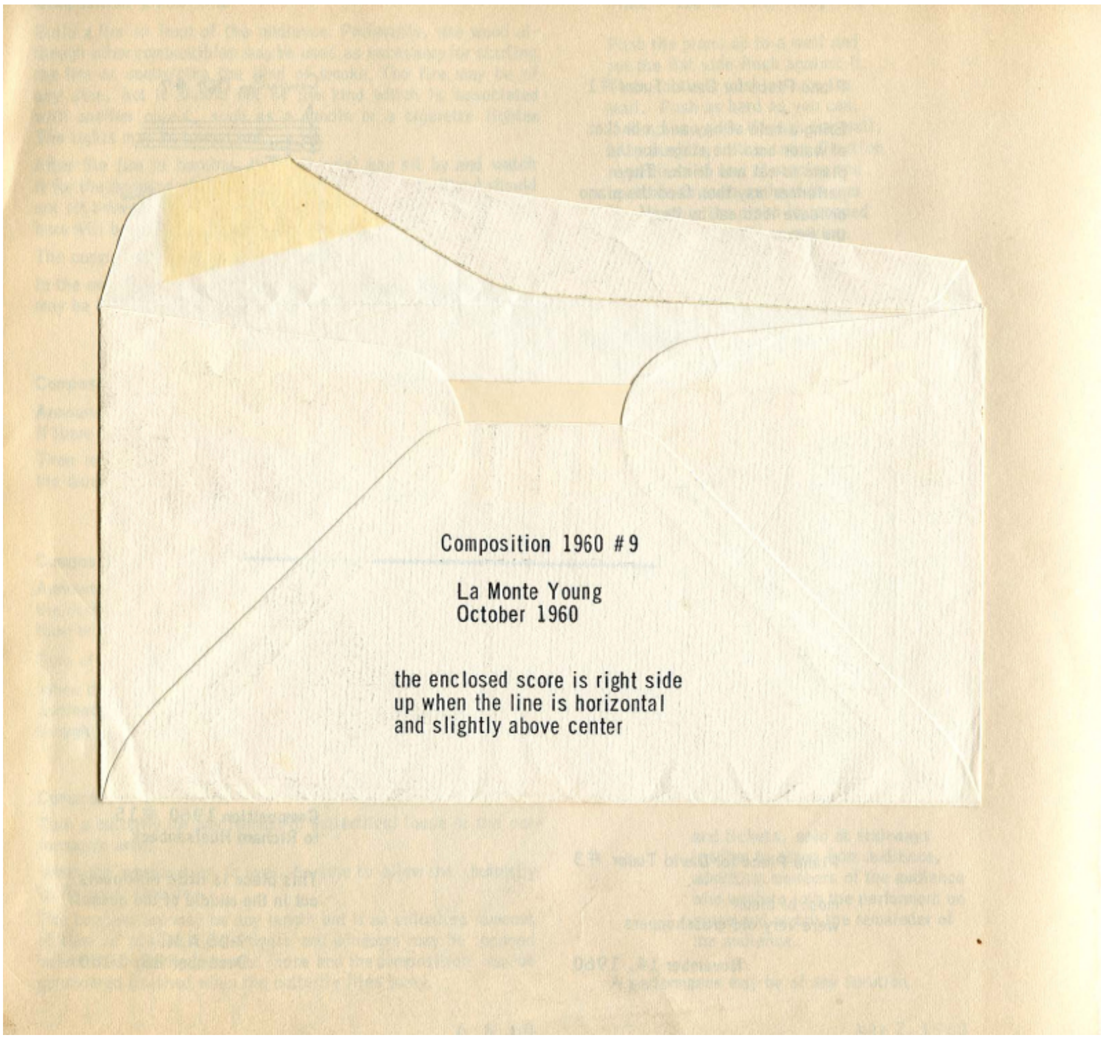



**FIGURE 22: Young, L. *Composition #9.* (1960)**

Since the earliest times of human existence, sound and hearing have functioned as a means of orientating us in space, allowing us to communicate and facilitating the reinforcement of social bonds. Sound art certainly has the potential to reactivate these primary functions of hearing. In my view, art of this kind will become an increasingly important means of reclaiming and reinventing the experience of Johannesburg.

This paper began with a discussion about the origins of hearing, the primary purpose of which was communication as well as to provide the organism with an acoustic image of the environment. Binaural cues, sound source localisation and stream segregation were all necessary for early humans to monitor their environment but also became a primary factor in communication between them. Evidence from different archaeological sites was presented to suggest that our early ancestors were particularly sensitive to the acoustics of their environment. Furthermore, because music and language seem to have developed in parallel, it is likely that music developed as a means of communication as well as a means of reinforcing social bonds. The particular kinds of sensitivity required for music-making, and the two interlinked purposes of music, were defined as important issues in relation to the soundscape of Johannesburg and pertinent to questions that relate to this soundscape – particularly when considering that the biological mechanisms for hearing have not changed since the Palaeolithic era. Even though it is difficult to predict what bearing future archaeological findings might have on our current understanding, there is still potential for further research in this field, especially with the advancement of acoustic imaging technology.

The development of music is important to the emergence of sound art. The art of orchestration, the use of space as a composed element in music, the inclusion of mechanical sounds into the domain of music and the influence that music had on recording and playback technology, are some of the primary ways in which music contributed to the emergence of sound art. On the one hand, the use of sound in art developed with the emergence of site-specific art; on the other, sound often was an incidental part of many other art forms such as performance art and installation art. These developments culminated in the exclusive use of sound and the emergence of sound art.

There were many early attempts to bring the phenomenon of sound art under discursive control, and not surprisingly given the definitional difficulty of sound art. Drawing from the historical narrative of sound and from Tierry de Duve's aesthetic theory, an attempt to set precise limits for the definition of sound art was made. This resulted in a working definition for sound art: sound art is a form of art that foregrounds sound in relation to the experience of time and space.

In reaching this conclusion I attended primarily to the history of Western music; a more global perspective would have to be a subject for further research. Understandably, for the purposes of this study it was deemed sufficient to initiate the re-reading of music from the perspective of sound. The study of the physical behaviour of sound waves and the biological mechanisms of hearing provided many useful conceptual tools that allow for a fuller understanding of sound. This understanding is helpful for two reasons. Firstly, for making quantitative judgements about why sound behaves differently in different environments and, secondly, for showing the similarities and differences between human hearing and other hearing organisms.

As certain environmental conditions change, so, too, do the acoustic signatures of a particular environment. There is a general indifference to the human impact on the special acoustics of the environment and its sounds. There is much potential for further research in environmental acoustics and bioacoustics and work in this field is also an urgent task considering broader questions related to environmentalism and ecological awareness. It is my view that the role of technology will be important in helping to preserve these soundscapes and in helping us hear the sounds of these environments that have yet to be heard.

Even though the physiology of human hearing has not changed much since prehistoric times, the environments in which hearing occurs have been drastically transformed. One of the more important facts that an analysis of the perceptual world of sound has revealed is that auditory perception has become habitually automised. This inattentiveness, more so a feature of the urban environment than of the rural, seems to work in complete opposition to one of the original purposes of hearing: as a means of providing an acoustic image of the environment. What further complicates the matter is that, in Johannesburg, spatial segregation along racial lines has predisposed its inhabitants to a particular kind of listening that tends to use the same spatial lens as a frame of reference.

Johannesburg's spatial legacy and the way it is heard is, however, continuously being undermined by the nature of sound and hearing. Sounds travel beyond spatial boundaries and hearing, too, can project itself past physical demarcations. Sound once mediated the forging and reinforcing of social bonds. Given the divided soundscape of Johannesburg, is it at all possible that sound artists could be agents in invoking a new sensitivity to the acoustic environment and making use of sound as a means of reinforcing social bonds?

What emerged from a brief critical survey of sound art in Johannesburg is that the relationship between sound and space in Johannesburg is still largely unexplored and has much potential. Approaches to the soundscape have been relatively generalised and lack the kind of nuance that would allow one to speak of the intricacies of the sound and the interrelationships between sounds of particular spaces. There is also potential for the exploration of how the sounds of different spaces overlap and interweave. The manner in which sound artworks project into space, also into public space, has been neglected and there is still much potential for sound art to interfere with the social divides that characterise the way we still live in Johannesburg. It is my hope that, by drawing from a diverse range of disciplines, this paper has managed to elicit a broad range of trajectories for future research in sound art as well as stimulate further conversations between sound art theory and practice. There is clearly a growing diversity and receptivity within the culture of audibility in Johannesburg and, in my view, the question of the role of sound art in this auditory world will become even more pertinent in the future.

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Figure 22: Young, L. (1960) Composition #9, in Maciunas, G. *Flux Box #1*, Collaborative Book Artwork by Various Artists, no page numbers.

# APPENDIX

## ITEM 1:

Maes, L. & Leman, M. (2017) Defining Sound Art, in Cobussen, M., Meelberg, V., & Traux, B. (eds), *The Routledge Companion to Sounding Art.* London & New York: Routledge. 29-34

Chapter 3 refers to a recent attempt to define sound art by way of 13 criteria. Below extracts from the list is provided:

1. **Concept:** Sound forms the starting point for the artwork. Sound should not serve to support visual elements; rather, the visual elements serve to support the sound.

2. **Perception:** The audience often steps into the work and is part of the work. The perception of the visitor has been individualised as the visitor's route and time spent determines the perception and experience.

3. **Space:** When sound is employed, the given space automatically serves as a resonator of the produced sound and, as a consequence, it has an influence on the work and becomes part of it. In some sound artworks this is explored by using sound to complement, contrast, or emphasize existing features of a space. Other works create their own space within a given location, for example with the aid of directional speakers, the distribution of sound sources in space, or the deployment of sound absorbing, reflecting, or redirecting material. Artists also opt to have complete control over the space by accommodating their work in specifically built constructions.

4. **Site Specificity:** Site-specific sound artworks can make use of certain physical characteristics of a space, but they can also be based on its current, former, or future function, its social context, its history, the existing sound environment, or other environmental factors. In most site-specific works the surroundings contribute to the atmosphere of the work and to the way the work is experienced. In the creation of a site-specific sound artwork, the artist often treats a complete space as one situation that can be entered by the visitor.

5. **Open Form:** We use the term open form here to refer to a work of art without a clear-cut beginning or ending. The non-time-bound character of visual arts manifests itself in sound art through the open form. Whereas most performances have a fixed beginning and end, sound art is like a performance lasting 24 hours a day, 7 days a week. The visitor decides when and how long s/he attends the performance. The sound artwork starts when a visitor enters and stops when that visitor is

leaving. The duration of attendance can vary highly and is not determined beforehand.

6. **Interaction:** In much installation art, the participation of the audience is often limited to pressing a button, turning a switch, or triggering a motion detector to activate the work. Once it has been activated, either consciously or unconsciously, a pre-programmed process cannot be interrupted or influenced by actions of the audience. However, more interactive installations are possible. A two-way interaction may lead to the emergence of essential qualities of the work. The visitor is then inclined to listen, to analyse the effect of his or her actions, and to manipulate the system. In general, we believe that interaction, with or without the use of technology, forces the visitor to listen and to be actively involved. In that way interaction does not only have an influence on the course of the work, but also on the perception of the work, because actions may determine perceptions.

7. **Production of Sound:** In sound artworks sound can be generated by electronic, electro-acoustic, or acoustic means or any combination of these. When sound is created electronically, vibrations are being generated through electronic or digital oscillators and circuits. When sound is generated acoustically, the sound is not electrically amplified. If sound is created acoustically and it is thereupon amplified, the sound is generated electro-acoustically.

8. **Performer:** Sound artworks very rarely rely on performers. The traditional music performer is replaced by either the visitor, animals, or environmental elements. In these cases, randomness becomes an important factor as the generation of sound happens in an aleatoric way. In other sound artworks the generation of sound may be automated. And although many automated sound artworks follow a mapped-out route, elements of chance can also be implemented in automated works, for example through the use of algorithmic software.

9. **Narrativity:** In sound art there is seldom a role for narrativity, here understood as a development of musical material, that is, a series of connected events that may make up a story. It is distinct from a dialogue that is based on interaction, or from sonic units that respond on actions. In most cases, the sonic discourse has no clear-cut beginning or ending; an open form is used. The sound is usually disconnected from the notion of the development of the material which characterizes most music. Although time-based arts can never be truly static, sound artworks tend to have a more static character and a greater musical structure is rarely present. As a consequence, most sound art has no linear argument and lacks narrativity as is the case in most music.

10. **Implementation of Techniques and Technology:** Sound art often makes use of new techniques and technologies. Technology to record and reproduce sound made it possible to separate sound from sound source and to create new constructions of sound, light, and objects.

Sound art is not one practice that can be taught as many skills can be involved in the very diverse manifestations of the art form. Three different points of departure can be distinguished as far as techniques are concerned. The artist can start from an existing technology; the artist can develop the technical material needed for the realization of a particular artistic concept; the artist can start from an existing technology and alienate it from its original use.

11. **Visual Component:** Sound art always comprises a visual component, as do all music performances. Even when all the sound-producing elements are hidden and no extra visual elements are added, there is always a material aspect to a sound artwork, namely the space where the work is presented.

12. **Endurance:** Sound art is rarely permanent or semi-permanent. Most sound artworks are temporary artworks, put up for a specific exhibition or event. Even works that are intended to be permanent often have a use-by date, as either the employed technology becomes outdated or environmental factors, on which the work is based, change.

13. **Place of Presentation:** The place of presentation gives an indication of the nature of the work. Besides in traditional art spaces such as museums and galleries, sound artworks are often presented in alternative locations and public spaces. The state of mind of the audience is different in public spaces as the majority of the “visitors” are passers-by who do not expect to encounter an artwork on their way.

**ITEM 2:**

*Sound: An Exhibition of Sound Sculpture, Instrument Building and Acoustically Tuned Spaces. Los Angeles Institute of Contemporary Art.* (1979) 12” Record published as a catalogue of artists featured in the exhibition

Track List:

Side A:

1. Jim Hobart: Maraca Instrument
2. Bob Bates (2): Force Field, performed by Gail Bates
3. Richard Dunlap: The Rubber Band
4. Joan La Barbara: Q-uatre Petites Betes Quatre Petites Bêtes?
5. Ron George: Improvisation
6. Ivor Darreg: composition for Turkish Fretless Banjo
7. Bob Wilhite: Two Spinners, performed by David Sabol
8. Jim Gordon (2): Piece for Synthesizer, Computer and Other Instruments
9. Paul De Marinis: Pygmy Gamelan Goes To Art

10. Jim Pomroy: Back on the Ladder, The Beat Goes On
11. Yoshi Wada: An Adapted Bag With Sympathy III
12. Christina Kubisch: Tempo Liquido
13. Gerald Oshita: Water Preludes

Side B:

1. Tom Jenkins: One Man Band
2. Bill Fontana: Kirribilli Wharf
3. Doug Hollis: Aeolian Harp
4. Tom Marioni: Drop Brushing
5. Terry Fox: Labyrinth Scored for II Cats
6. Tom Recchion: Solos
7. Alex Bernstein: L.A. Propper
8. Karen Wolff / William Kingsbury: Double Crossing
9. Bruce Fier: Score for Eleven Infinite Rainbows
10. Susan Rawcliffe: Trix Ocarinas, Composed by Anna Rubin
11. Will Parson / Grace Bell: Road Runner / L.A.
12. Dennis Evans: Location # 2
13. John Duncan / Michael le Donne-Bhennet: Koko Weef 6038

**ITEM 3:**

Glass, P. (2004) *New Music, New York: From The Kitchen Archives 1979*. Orange Mountain Music. Produced by Stephen Vitiello & Don Christensen

Track List:

Disc 1:

1. Philip Glass: Dance no. 4
2. Meredith Monk: Do You Be
3. Jon Gibson: Criss Cross (Selection 3)
4. Garrett List: Where We Are
5. Gordon Mumma: Schoolwork
6. George Lewis: The Kim and I
7. Michael Nyman: Five Orchestral Pieces for Opus Tree
8. Pauline Oliveros: The Tuning Meditation

Disc 2:

1. Tom Johnson: Secret Songs: Wolo Yolo

2. Tom Johnson: Secret Songs: Dwa
3. Tom Johnson: Secret Songs: Paka Laka
4. Charlie Morrow: Dream Song/Vision Chant
5. Barbara Benary: Exchanges
6. Phill Niblock: Four Arthurs, superimposed with Two Octaves and Fifths
7. David Behrman: Touch Tones
8. Joel Chadabe: Solo
9. Tony Conrad: Untitled Pieces
10. Charlemagne Palestine: Untitled for Solo Voice
11. Steve Reich: Drumming, Part One.

**ITEM 4:**

Environment Conservation Act, 1989 (Act No. 73 of 1989)

Noise Control Regulations, 1999

**"noise nuisance"** means any sound which disturbs or impairs or may disturb impair the convenience or peace of any person.

Part II: Noise Pollution Management.

Prohibition of Disturbing Noise.

8. No person shall make, produce or cause disturbing noise, or allow it to be made, produced or caused by any person, animal, machine, device or apparatus or any combination thereof.

Prohibition of Noise Nuisance.

9. No person shall –

   (a) operate or play, or allow to be operated or played, a radio, television set, drum, musical instrument, sound amplifier, loudspeaker system or similar device producing, reproducing or amplifying sound so as to cause a noise nuisance;
   (b) offer any article for sale by shouting, ringing a bell or making other sounds or by allowing shouting, the ringing of a bell or making of other sounds in a manner which may cause a noise nuisance;
   (c) allow an animal owned or controlled by him or her to cause a noise nuisance;
   (d) discharge fireworks in a residential area in a manner which may cause a noise nuisance;
   (e) build, make, construct, repair, rebuild, modify, operate or test a vehicle, vessel, aircraft or object near residential premises, or allow it to be built or made, constructed, repaired, rebuilt, modified, operated or tested, if this may cause a noise nuisance;

(f) erect a building or structure on residential premises or allow it to be erected if this may case a noise nuisance;

(g) use or discharge any explosives, firearms or similar devices that emits impulsive sound and may cause a noise nuisance, or allow it to be used for discharge, except with the prior consent in writing of the local authority concerned and subject to such conditions as the local authority may deem necessary;

(h) on a piece of land or water or in airspace above that piece of land designated by means of a notice in the press –

(i) move about on a recreational vehicle; or

(ii) exercise control over a recreational vehicle; or

(iii) as the owner or person in control of the piece of land, water or airspace, allow such activity to take place;

if this may cause a noise nuisance;

(i) except in an emergency, emit a sound, or allow a sound to be emitted, by means of a bell, carillon, siren, hooter, static alarm, whistle, loudspeaker or similar device, if it may cause a noise nuisance;

(j) operate any machinery, saw, sander, drill, grinder, lawnmower, power garden tool or similar device or allow it to be operated in a residential area, if it may cause a noise nuisance;

(k) load, unload, open, shut or in any way handle a crate, box, container, building material, rubbish container or any other article, or allow it to be loaded, unloaded opened, shut or handled, if this may cause a noise nuisance;

(l) drive a vehicle on a public road in such a manner that it may cause a noise nuisance;

(m) use any power tool or power equipment used for construction work, drilling work or demolition work, or allow it to be used, in or near a residential area if it may cause a noise nuisance;