Are You in Tune?

A Phenomenological Enquiry into Pythagorean Tuning in the Creation of New Music

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Abstract

This research explores the experiential and practical performance aspects arising through using Pythagorean Tuning. The focus is primarily on the application of the tuning system in the creation, performance and apprehension of new music. In Western cultures, equal temperament is the dominant tuning standard to the extent that musicians and audiences may not be aware of other tuning possibilities. However, using non-tempered tuning standards arguably produces a different physical experience in the listener and a different quality of physicality in sound production on a musical instrument. The questions arise: How do people experience non-tempered tuning? How do musicians respond to the demands of playing in tuning systems that are not familiar and may work counter intuitively to the architecture of the instrument they play? Does the experience of the musician using different tuning systems enhance or detract from other performance attributes?

This research is supported by practice led enquiry where the primary researcher collaborated with a number of producers to create an original album of contemporary music. A second album was produced which explored a range of musical styles through re-imaging Christmas carols. Together the two albums form the creative submission which provides a diversity of musical styles and artistic approaches using the Pythagorean tuning system.
Declaration

I Miranda Jensen declare that this thesis comprises the original work of the author towards the award of Doctor of Philosophy except where indicated in the Preface. Due acknowledgement has been made in the text to all other material used. The thesis is fewer than the maximum word limit in length, exclusive of tables, maps, bibliographies and appendices.

Signed _______________________
Miranda Jensen 01/08/2017
Preface

This thesis is the original work of Miranda Jensen and includes a summary of each of the collaborations that contributed to the original album that is part of the creative submission. Within this thesis text has been contributed by some of the collaborators on their experience of the project and where such inclusions are made, credit is attributed to the collaborator. Where creative works are the product of a collaboration with a producer, the instrumental accompaniment is generally the work of the collaborator and the lyric and vocals the work of the primary researcher. In some instances, final mixes were provided by the producer and in other instances they were completed by the primary researcher.

No aspect of the thesis or the creative works have been submitted for other qualifications. One of the Christmas Carols submitted as part of the Christmas album was completed prior to enrolment in this degree, however, it was the first experiment of the tuning system in question and contributed to the application process to undertake this study. One of the original songs had been co-written prior to undertaking this degree, however was selected to be produced due to its harmonic structure, similarly a second song was also selected from my back catalogue for inclusion.

An independent proof read was performed by a family member who is a secondary school teacher but not familiar with the content covered in this paper. Funding for the presentation of this research at conferences was provided by the Victorian College of the Arts, Faculty Small Grants. Funding was also provided from the same source for the final mastering of the original album.
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Introduction

This thesis explores the experience of Pythagorean Tuning (PT) when applied to the practice, writing and production of new music. The practice led component and creative submission has been undertaken from the perspective of a contemporary vocal artist. The phenomenological approach has enabled a whole of person exploration, which has resulted in the overarching finding that; PT provides a different experience.

The research provides invaluable information for anyone embarking on a journey of composing, arranging, recording and performing in PT. The areas of learning covered throughout this thesis include; tuning a piano in PT, experiences in adapted music software (DAW’s and plugins), practicing with PT, performing live with PT, physical experiences associated with PT and adapting existing songs from Equal Temperament (ET) to PT.

Chapter 1 provides background information that contextualises the research across related disciplines. Information includes a historical account of tuning, Pythagorean philosophy, societal influences and a mathematical understanding of temperament. Chapter 2 details the aims, scope and approach undertaken for the research demonstrating the relevance of the study and how it contributes new thinking in the field.

Chapter 3 accounts the main research activities, with a summary of findings from the practice led components of the study. The dialogue provided on each of the collaborations provides an immersive understanding of the experience of PT when producing a contemporary album. Chapter 4 indicates the potential applications and benefits of working with PT through discussion on conceptual considerations and practical application with instruments and technologies. This final chapter establishes and surmises the range of further avenues of enquiry that have been opened through this research.
Chapter 1 - Background

Pythagorean Philosophy

For the purposes of this research it is necessary to understand something of Pythagoras, his life, work and philosophy. This understanding provides context for the application of his tuning in the creation of new music. Riedweg, author of *Pythagoras: his life, teaching, and influence* stipulates that Pythagoras called himself a philosopher after introducing the term philosophy (Riedweg 2005 Pg92).

There has been some scholarly research on Pythagoras and aspects of his life, however, this is open to speculation due to limited resources that have survived and there will be things that are never known as they were never documented at the time. As a result, people have drawn conclusions from the fragments of scarce documents, observations and anecdotes that remain from this time. Riedweg provides that the Pythagoreans held secrecy in such high regard, that many of their reflections were never written down (Riedweg 2005 Pg43). The most definitive account of the Pythagoreans take on music is captured in volume nine of Iamblichus (Riedweg 2005 Pg127).

It is difficult to discern what is true of Pythagoras the individual as opposed to the Pythagorean school of thought. What is definitive is that he was a Greek philosopher known as Pythagoras of Samos (c.560–480BCE). Beyond this, it is likely that he was a natural leader, with so many following his teachings. In Vogel’s book, *Pythagoras and Early Pythagoreanism* he outlines how Diodoru and Trogus (authors on the Pythagoreans) described him as being a great orator (Vogel 1966 Pg221).

With the lack of reliable information, it is reasonable to consider whether the story of how Pythagoras discovered his pure ratio scale is fact, fiction or elaboration. The story involves Pythagoras hearing a hammer beating on an anvil and realising that it was the weight of the hammer that resulted in changing pitches. The story continues that he subsequently established an experiment using hanging strings with different weights attached to determine the ratios (Riedweg 2005 Pg28).

Regardless of the accuracy of the stories, the Pythagoreans were clearly a powerful philosophical collective where they would explore, analyse and communicate their early philosophical musings. In his book *The Just Intonation Primer*, Doty outlines how those that focussed purely on the musical philosophies became known as the harmonists. It is this group that is largely accountable for the information we have documented from this time as their findings were summarised by Claudius Ptolemy of Alexandria (c.100-170AD) in the second century (Doty 2002 Pg2).

Godwin refers to the harmonists in his book *Harmonies of Heaven and Earth: Mysticism in Music from Antiquity to the Avant-Garde*. He describes how they are an early form of what we would call today a music therapist with their ability to use music to effect change upon emotional states (Godwin 1987 Pg23,29). An excerpt from *Pythagoras and His School*, describes how the Pythagoreans would achieve this by working with the energy states of the physical body:
“And, of course, from the beginning of learning, the students were taught the art of working with their energy structures: to cleanse them, to move the concentration of the consciousness between different chakras and meridians.”

(Anna Zubkova 2008 Pg575)

There are however, those who have questioned the legitimacy of Pythagorean approaches. In On the Sensations of Tone, Helmholtz suggests that the Pythagoreans were forming theories without solid evidence:

“This relation of whole numbers to musical consonances was from all time looked upon as a wonderful mystery of deep significance. The Pythagoreans themselves made use of it in their speculations on the harmony of the spheres.”

(Helmholtz 1954 Pg41)

Further aspersions are made by Ball in his book The Music Instinct: How Music Works and why we can’t do without it, who argues the irony of Pythagoreans being so focussed on harmony when their musical practices were largely monophonic. The extent of musical practice at this time would be that of a doubling of a vocal line in unison with an instrument (Ball 2010 Pg51). Ultimately the credit of PT first being used by the Pythagoreans is in question. Heller references anecdotes suggesting earlier use of PT in his book Why You Hear What You Hear: An Experiential Approach to Sound, Music, and Psychoacoustics. The anecdotes are from Babylonian texts from approximately one thousand years earlier that contain tuning concepts of a similar nature (Heller 2013 Pg517).

When introducing this research on PT to various audiences, it has generally been known that Pythagoras was a mathematician who informed musical practices. However, it was not generally known that he was more of a holistic being. Pythagoras seems to have had broad interests such as diet, astrology, mathematics, politics, music, philosophy and religion. These interests seem to have all been underpinned by a concept of harmony. Vogel went so far as to describe this harmony, achieved through balance and ratios, as a maintenance of weight, health and emotions where even his mood would be maintained at a “mild joy” (Vogel 1966 Pg178). It appears that the understanding that; Pythagoras was a mathematician who informed music, is what remains of the tangible things that could be attributed to him. Whereas the intangible practices that are more experiential in nature; energy, emotion, balance and harmony, have been harder to communicate through time.

In death, it is apparent that Pythagoras’s thought leadership segregated into two disciplines, the acousmatics and the mathematicians (Riedweg 2005 Pg136). This division of the thought leadership is significant to this research as one of the challenges has been the segregation of the artistic and mathematical knowledge bases. An example of how these two different ways of thinking has caused much debate is the views on the Pythagorean comma. In a mathematical sense the system is incomplete because it doesn’t neatly close. However, there are differing views on the philosophical and artistic side. In a blog post on the emergence of A=432hz, Schotsborg argues the case of the comma:
“The Pythagorean comma is not a ‘mistake’ of nature, it is the arrogance of the Western thinking that has called this a mistake and tried to solve it. The Pythagorean comma is what makes the music ‘cosmic’, it will let the overtones transcend infinitely.” (Schotsborg 2013)

This challenge on the need for the scale to neatly close is significant to this research as I have experienced benefits in the incompleteness of PT caused by the comma. I cannot attest however that the comma was a planned application of the PT system by Pythagoras or his disciples. It is likely that due to the nature of the Pythagoreans music and instrumentation at the time, the idea of the comma was insignificant.

**Early Examples of Natural Tuning**

Whilst researching Pythagoras there were references to earlier explorations of tuning and pure ratios. In his book, *How We Hear Music: The Relationship Between Music and the Hearing Mechanism* Beament provides an earlier example. He highlights that the Chinese are credited with the creation of seven-holed flutes from 9000 BC with a “scale approximating to simple pitch-frequency ratios” (Beament 2003 Pg148). The oldest example of a flute was approximately 44,000 years old carved from the bone of a young cave bear, however there was no acknowledgment of tuning (Ball 2010 Pg18).

Whilst it is fascinating to explore these early examples, the consistent theme in each is the primitive nature of the sounds created by the instruments. For example; the Greek Lyre’s that were referred to by Beament as “little more than strummed percussion instruments” (Beament 2003 Pg29) or the early flutes making very little periodic sound. We can assume that these early instruments were a process of discovering what was aesthetically pleasing which may have resulted in some form of pure ratio being inherently sought by their creators.

In his *Introduction to Historical Tunings*, Gann informs that in the 13th and 14th centuries the French Academy at Notre Dame was committed to 3/2 ratios and the adoption of PT. It is apparent though that the lines between Just and Pythagorean were blurring in the lead up to Meantone Temperament (similar to PT, with narrower perfect fifths). Whilst PT was generally appropriate for compositions at this time, experimentations around perfecting temperament were occurring and musical styles were changing. It was acknowledged that the wider third of PT (albeit by my calculation only 2.6 cents wider) was beneficial for accentuating the resolution to a perfect fifth, however it is difficult to discern the accuracy of any temperament at this time.

According to Jorgensen and his *Tuning Compendium*, PT was not documented until 1518 by Heinrich Scribeber (alias Henricus Grammateus) (Jorgensen 1991 Pgxxii) it is therefore likely that any preference for temperament in the 13th and 14th centuries was inconsistent in understanding, application and consistency.

In 1558, Gioseffo Zarlino, the choir master of St Mark's Church in Venice formalised Just Intonation (Ball 2010 Pg58). The 1500’s were significant for temperament, according to Ball, ET was first published in 1584 by Chu Tsai-Yu, a prince of the Ming dynasty and Chinese scholar (Ball 2010 Pg61).
A focus on understanding temperament occurred for the next few hundred years. In the *Just Intonation Primer* Doty highlights that in the 16th and 17th centuries there were examples of keyboards with more than 12 notes in the octave created, however the exploration of alternative temperaments, not instruments, became the dominant path of inquiry at this time (Doty 2002 Pg3).

**Developing Temperament Accuracy**

From the 1500’s through to the 1700’s there were many discoveries that contributed to the increasing awareness of temperament accuracy. Heller advises that Galileo Galilei (1564-1642) was likely to be the first person to record sound, (Heller 2013 Pg93) he used brass plates to create a permanent record of what was audible. In Alexander Wood’s *The physics of music*, Wood outlines how the determination of frequency was made by Mersenne (1588-1648) who, similar to Pythagoras’s legend of determining ratios with strings and weights, experimented with a hemp rope. He made this over 30m long combined with a brass wire 43m long so that the vibrations were slow enough to be seen by eye (Wood and Bowsher 1980 Pg44).

As the understanding of temperaments developed and they became more accurate interest in ET, where there are 12 equal divisions of the octave, increased. Mersenne, as well as determining frequencies, is credited to be one of the first to document ET in his book the *Harmonie Universelle* (1639). In practical terms, it was keyboard instruments in Germany that were first to adopt ET tuning, with some organs beginning to be tuned this way late in the 1600’s. However, ET was not widely adopted at this time. Meantone temperament became the predominant system in France and England through to the 1700’s and 1800’s respectively (Doty 2002 Pg4).

Whilst it is well acknowledged that through Bach’s time (1685-1750) that ET was being applied, others still investigated other temperaments, and as Pierce highlights in his book *The Science of Musical Sound* musicians preferred not to use it (Pierce 1983 Pg22). Heller outlines another significant development in the exploration of pitch with the invention of the tuning fork by John Shore in 1711. The tuning fork provided a level of accuracy unparalleled by other devices at the time as it enabled the development of frequency standards (Heller 2013 Pg56).

The theorists continued their explorations of temperament throughout the 1700’s with Duffin capturing the following account in his book, *How Equal Temperament Ruined Harmony (and Why You Should Care)*:

“Johann Georg Neidhardt, a theorist who Bach knew, said of it in 1732: Most people do not find in this tuning that which they seek. It lacks, they say, variety in the beating of its major 3rds and, consequently, a heightening of emotion. In a triad everything sounds bad enough; but if the major 3rds alone, or minor 3rds alone, are played, the former sound much too high, the latter much too low.” (Duffin 2008 Pg45)

The introduction of measuring beats to tune instruments was discovered in 1749 by Robert Smith (Jorgensen 1991 Pg3). It is apparent that through these many centuries from the initial conceptual identification of ET through to its wider adoption there were
two vastly different approaches; the technical and the aesthetic. This is the same divide that occurred following the two schools of thought evolving from the Pythagoreans.

Possibly the most significant contribution to the debate of temperament at this time was Bach’s Well Tempered Clavichord (1722) which, over the years has caused much consideration of its purpose and intent. It is significant because it brings together the conceptual, theoretical approach by exploring compositions in all 24 keys, whilst also providing an aesthetic comparison of their merits. The long-held assumption that the composition was a demonstration of ET fails to acknowledge that Well Tempered at this time referred to different keys having different characteristics. It was also believed that these different characteristics created beneficial colouring of the music and enhanced emotional effects (Doty 2002 Pg4).

It is difficult to discern Bach’s intent, or preferred tuning for the work, however the following account in Johann Nikolaus Forkel’s 1802 biography demonstrates the fluid nature of tuning at this time due to inherent preferences:

“Bach tuned his own harpsichords and clavichords and found other people's tunings unsatisfactory; his own allowed him to play in all keys and to modulate into distant keys almost without the listeners noticing it.” (Contributors)

This quote suggests that temperament was less about the system and more about the connectedness to an individual’s personal experience of the tuning. This idea of inherent tuning and personal preference was further highlighted by the accounts of other musicians at this time. In his book, Intonation for strings, winds and singers, Podnos accounts how  “Bartolommeo Campagnoli (1751-1827) introduced the aesthetic practice of raising sharps higher than the enharmonic flats (i.e. G# higher and Ab lower)” (Podnos 1981 Pg11).
Societal Influences and Environment

It is important to acknowledge what was occurring in society at this time. This is a relevant course of inquiry to the consideration of technical versus aesthetic explorations of temperament for late in the 1700’s was the start of the Industrial Revolution. Until this time, temperament had largely been driven by an understanding of sound where decibels were contained. In his book, *The Tuning of the World*, Schafer points out that the loudest device at this time roughly equated to the sound of the black-smith’s hammer (*Schafer 1977 Pg58*).

Schafer articulates the influence of our environment on musical composition, which would also extend to tuning preferences for these compositions:

> “Consider, for instance, two composers, one living in that century and one living in our own. The former travels everywhere in a carriage. He can't get horses hooves off his brain and his tunes all go clippety-clop to the opera shop. The latter travels everywhere in his sports car. His music is remarkable for its drones, clusters and whirring effects.” (*Schafer 1977 Pg112*)

Schafer further outlines how sailors, farmers, flower girls and a range of human labourers were all driven by their connectedness to one another through breathing or moving in synchronized patterns (*Schafer 1977 Pg63*). This connectedness would be expressed through work song, however, as the decibels of machinery increased in the industrial revolution, work song was wiped out, and the productivity of workers re-aligned to mechanical revolutions per minute (*Schafer 1977 Pg64*).

Similarly, the street criers, the very expression of emotion joined with amplitude, were drowned out by the automobile’s invention (*Schafer 1977 Pg67*). It was not so much just the sound of the industrial inventions that were part of a turning point in relation to the exploration of temperament, but the effect of the vibrations associated with it. D.H. Lawrence (1915) referred to the sounds of this time as a “narcotic to the brain” (*Schafer 1977 Pg74*) which is a significant concept for this research, it prompts the question; how did the industrial revolution impact our connection to our inherent tuning preferences?

The impact of the increase in machinery was not insignificant, up until this point there were no sound restrictions or hearing protections. It wasn’t until 1890 when “Barr surveyed one hundred boiler makers and discovered that not one of them had normal hearing” (*Schafer 1977 Pg75*). These concepts are significant to this research as they contrast the assumed premise that the shift from PT to ET was based on the merits of the tuning systems as they related to their musical application. Rather, it was likely influenced gradually by a cacophony that could not be traced at the time or now in retrospect. With such substantial societal and environmental change, it is possible that the subtleties of pure ratio awareness were effectively drowned out.
Inventions and their Impact on Temperament

The 1800’s held a number of significant innovations for the capturing, identifying and re-producing of sound waves. Spurred on by the technological advances of the Industrial Revolution there was the rise in popularity of the Chaladni Plates (Heller 2013 Pgxxi), the invention of the Siren by Cagniard de la Tour (1819) enabling the periodic nature of frequency to be accurately measured, and the evolution of the Phonautograph to visually record and reproduce sound. The development of this last device seemed to span almost the whole century. The first part of its discovery is credited to Thomas Young who first conceptualised it in 1807 as a “moving stylus connected to a tuning fork over a wax coated revolving drum” (Schafer 1977 Pg125). It is then credited to Edouard-Leon Scott de Martinville as being the first person to make the phonautograph in 1860 (Heller 2013 Pg95). It is further acknowledged that Martinville was unaware of its ability to re-create sound audibly and this part of the Phonoautograph evolution is credited to Thomas Edison in 1877, with the device being later known as the Gramophone.

Other significant discoveries are outlined in the book Quadrivium: The Four Classical Liberal Arts of Number, Geometry, Music, & Cosmology. Firstly they mention the Kaleidophone which provided images of harmonics, invented by Sir Charles Wheatstone in 1827 (Lundy, Sutton et al. 2010 Pg230). In 1834 Johann Heinrich Scheiber created the Tonometer (Jorgensen 1991 Pg1) which led Scheiber to propose that 440hz be accepted as the tuning standard in Germany, which it was in 1834 (Helmholtz 1954 Pg48). Similar to the Kaleidophone, Professor Blackburn created the Harmonograph in 1844, a device that creates images of musical harmonies joining together sight with sound (Lundy, Sutton et al. 2010 Pg185). And similar to the Chaladni plates Margaret Watts Hughes created an Eidophone in the 1880's, a version of the geometric shapes created by the plates that was more aptly used by the singer as it contained a tube that she could sing into (Lundy, Sutton et al. 2010 Pg234). These devices enabled a visual awareness of pure ratios that had previously not been available and yet it was at this time that ET had its biggest proliferation.

According to Duffin, by 1883 ET was well and truly established in England, with Pianos and Organs being tuned in the newer system for the last 30-40 years. Podnos further states that:

"ET's growing popularity during the nineteenth century influenced the Broadwoods piano-making firm of London to adopt such tunings for all of their pianos, commencing in 1846." (Podnos 1981 Pg9)

It is interesting to look back on the inventions that were occurring leading up to this time as they can be divided into two categories. The first category is those that visually represent sound; Chaladni, Kaleidoscope, Harmonograph, Eidophone, Phonoautograph. The second category is those that measured the periodicity and precise pitch of sound; Siren and Tonometer. Whilst there was clearly wide interest in the visual effect of the pure frequencies, it was the more practical application of devices that assisted in precise and efficient tuning. This enabled an increase in the development and standardisation of instruments, which made them more accessible than they had been up until this point. Duffin articulates this as a drive for efficiency and commercially driven decisions:
“The need to manufacture so many instruments quickly for this new market forced musical instrument makers to cut corners to streamline and simplify manufacturing techniques so that subtle tuning systems of several nineteenth-century instruments got replaced with basic ET systems. It was so much more convenient and cheaper to make instruments that way. Band music could truly be for the masses, but in a market-driven society, they could afford it only in ET.” (Duffin 2008 Pg141)

**Influencing Aspects of the 1900’s**

The 1900’s provided even more significant development than the 1800’s, starting from early in the century where precision in tuning was still somewhat of an enigma; following through to the end of the century with the proliferation of computer generated music. According to Duffin:

“**Before 1917 they may have called it ET, they may have thought they were tuning ET, but they weren’t. Even as far back as 1864, many years before his comments in the Helmholtz translation, Ellis worried that ET wasn’t really ET.**” (Duffin 2008 Pg112)

He also provided that by choice narrow and wide fifths were being used well into the twentieth century (Duffin 2008 Pg109). In the pursuit of setting standards at this time, according to Jorgensen, the mathematical principles of ET were universally accepted in 1917 (Jorgensen 1991 Pg3). Equally, in 1928, the decibel became widely used as a means of providing a measure for sound pressure (Schafer 1977 Pg76). And in 1939, at a conference held in London, A=440hz was accepted as the international tuning standard (Wood and Bowsher 1980 Pg49).

It was early in the 1920’s when listening habits began to change. In the early instances of radio, people would carefully select from the programming (Schafer 1977 Pg93) but this soon became a whitewash of background noise. Similarly, the proliferation of electricity contributed to this changed soundscape. Schafer described this phenomenon as follows:

“**Electrical equipment will often produce resonant harmonics and in a quiet city at night a whole series of steady pitches may be heard from street lighting, signs and generators. When we were studying the soundscape of the Swedish village of Skruv in 1975, we encountered a large number of these and plotted their profiles and pitches on a map. We were surprised to find together they produced a G-sharp minor triad, which the F-sharp whistles of passing trains turned into a dominant seventh chord. As we moved about the streets on quiet evenings, the town played melodies.**” (Schafer 1977 Pg99)

Schafer undertook a number of experiments to explore the instance of resonant frequencies that had become apparent with the use of electrical devices. In one study, students were asked to sing the tone of Prime Unity in different countries where the standard currents of electrical frequencies differed. The study found that students were singing the frequency that aligned to the electrical hum of their environment.
This occurrence of the environmental hum is significant to this research as it prompts the consideration of what led us to move away from pure ratios in music. Was our inherent tuning tainted by the environment through the 19th and 20th centuries? Did the new sound environment cause an internal conflict against our pure state by shifting our awareness away from our resonant frequencies and pure ratios? Were we unable to connect with natural frequencies through the industrial revolution and the ultimate proliferation of sound in our environment?

Not only was there an introduction of new sounds, but the loudness of these sounds was beginning to be understood with the development of the Isobel Contour Map. This map measures the degree of sound decibels across territories, and has become an overlay of the modern society (Schafer 1977 Pg131). This is an interesting aspect to the questions around the experience of PT as it prompts further inquiry on the prevalence of pure ratios in modern society and their potential benefits in areas that are considered to suffer from noise pollution.

**Natural Tuning in the Modern World**

From the mid 1900’s there are accounts of composers and artists alike that made a return to Just Intonation. Arguably there would have been others (such as string players in particular) that never really left the practice. Considering that prior to 1917 it was difficult to truly have an accurate and consistent ET, it is within a short window that pure ratios ceased and returned to use.

Harry Partch was influential in this movement; in 1947, he released *Genesis of a Music*, covering his approach to Just Intonation for composers. Partch had an extensive career of experimenting and evolving the approach to Just Intonation commencing in the 1920’s. He created theories, instruments, and compositions including major theatrical works using pure ratios (Doty 2002 Pg6). Similarly, in the 1960’s La Monte Young became known for his vocal performance group that used instrumentation and improvisation to explore pure ratios and harmonics. In 1964, he also composed a work on a justly tuned piano titled *The Well-Tuned Piano* (Doty 2002 Pg7). Doty further provides an account of how the continued proliferation of Just Intonation occurred in the 20th century:

“In the late 1970s and early 1980s the number of composers working with Just Intonation began to increase significantly, due in part to the development of affordable electronic instruments with programmable tuning capabilities and in part to the coming of age of the post World War II generation of composers. The achievements of Partch, Harrison, Johnston, Young, and Riley made it evident to these younger composers that Just Intonation was a valuable resource for composers of diverse styles and tastes, and the availability of electronic instruments with programmable tuning made it possible for the first time for composers to experiment with a variety of different tuning systems without having to invent and build novel instruments or to train performers in unusual playing techniques.” (Doty 2002 Pg7)
The late 1900’s are significant to this study as they mark the introduction of computer music. It was also a time that initiated technologies such as magnetic cassette technology (1963), the Walkman as a portable music device (1979), general MIDI interface (1983) and autotune plugins (1997). The autotune plugins feature prominently in the practice led component of this study as they allowed alternate tuning to be explored in unprecedented ways. Pierce provides an account of the first computer music generated in 1957 on software created by Max Matthews, his recollection includes a missive on his own composition Stochatta and the first composition created by a speech student, Newman Guttman, that focussed on pitch variations (Pierce 1983 Pg7).

By the end of the 20th century there is a perception that ET is a place where we have landed. There are a multitude of videos online that demonstrate alternative tuning systems but they do so as a historical account. Heller’s following dialogue is a perfect summation of this sentiment:

"ET has won the day, and its use is nearly universal, except when ancient music is being played the way it was written and meant to be heard, or when there are no fixed frequency instruments required, such as a capella choir or string quartet." (Heller 2013 Pg526)

In 2017 there is a clear movement of alternate tuning enthusiasts with social media groups dedicated to their exploration. Additionally, the term Xenharmonic music was coined by Ivor Darreg to explain microtonal music or music that doesn’t conform to ET. An alternate tuning group on the social platform Yahoo has over 1,800 members and the Facebook equivalent, called the Xenharmonic Alliance has over 1,900 members.

The intent of participants in these networks is unclear. Many questions can be asked; Are they interested in building a historical understanding? Composing or practicing with alternate tunings? Is it an interest or a movement? Doty, surmises that in previous centuries the search for temperament was to provide the system, whereas in the 20th Century, Partch and others have had a more localised intent to create tunings that best served their musical goals rather than one that “could serve the needs of the culture as a whole” (Doty 2002 Pg6).

Technology has played a role in this renewed interest as well. There are almost as many mobile devices as there are people in the world and there are many quickening trends on the types, means and methods of music consumption. The National Association of Music Merchants in America provide an annual report that highlights the impact of these changes. The report shows a decline in acoustic piano sales and an increase in digital and electronic keyboards over a ten-year period from 1997-2006 (NAMM 2007). With so much technological and societal change occurring, it seems premature to agree with Heller’s sentiment that ET has won the day. We can use the example of A=440 as an example of resistance around the world to standardisation. A list of approximately 100 documented orchestral tunings from 1715 through to 1880 explore the frequency of the note A, it shows a range from 409Hz to 457Hz. Many European orchestras to this day still adjust their concert A to achieve the desired ambience in their music (Swenson 2008).
The historical account provided has demonstrated that since the Pythagoreans there has been a divide between the mathematical and artistic aspects of temperament. It has also demonstrated that there has been a lack of enquiry into the understanding of an application of frequencies, through music, to explore benefits for the human experience.

**Physics of Sound**

For the purpose of this research, key background information to compliment the historical journey has been a basic understanding of the physics of sound. This research has provided a platform to understand what I was experiencing and how I was experiencing it. Building this understanding led to the consideration on what the outcome would be if young students were to study the physics of sound prior to building their musical awareness. This following section provides a summary of background information gathered through the research relating to frequencies. The section includes an understanding of frequencies in relation to physics, maths, temperament, colour and the phenomenon of beats and Just Noticeable Difference (JND).

This following exploration is pertinent to the phenomenological enquiry as it looks not only at the scientific aspects of temperament, but provides an understanding of the space in between. That is, what we are not hearing, or understanding mathematically, but what we are experiencing of the vibrations that accompany sound.

Physics, from ancient Greek, knowledge of nature provides us with an understanding of how the universe and all of its components behave. As Helmholtz describes it, the physics of wave forms is comparable in their behaviour on the surface of water and through the air, with the key difference being how sound traveling through space will fill all surrounding spaces, rather than only on the surface of the water (Helmholtz 1954 Pg35).

A musical understanding of frequency can be considered with the 88 keys on a piano. The keys range from approximately 27 to 4,000 Hz. Where a piano is tuned to ET; the octave (a doubling of frequency) is divided into twelve equal increments. However, the human hearing response is capable of discriminating more than 36 divisions of the octave. Similar to colour, there are many frequencies within the spectrum to be experienced.

Helmholtz provides a practical example of how the wave forms of sound operate in the environment:

“*Hear we have a number of musical instruments in action, speaking men and women, rustling garments, gliding feet, clinking glasses, and so on. All these causes give rise to systems of waves, which dart through the mass of air in the room, are reflected from its walls, return, strike the opposite wall, are again reflected, and so on till they die out. We have to imagine that from the mouths of men and from the deeper musical instruments there proceed waves of from 8 to 12 feet in length [c to F], from the lips of the women waves of 2 to 4 feet in length [c" to c'], from the rustling of the dresses a fine small crumple of wave,*
and so on; in short, a tumbled entanglement of the most different kinds of motion, complicated beyond conception.” (Helmholtz 1954 Pg52)

Schafer also provides an understanding of wave forms in nature; insects such as mosquitos and bees have wing oscillations that create an audible periodicity between four and over 1,100 beats per second (Schafer 1977 Pg35). Lions are another example, where they are known to roar with their mouth low to the earth to carry the resonance of sound across distances (Schafer 1977 Pg39). For the purposes of this research these examples highlight the ubiquitous nature of sound.

Schafer also provides a musical example referencing the cathedrals with long reverberation times off the stone walls cause the sound waves to envelop listeners. He quotes the Viennese music sociologist Kurt Blaukopf:

"The sound in Norman and Gothic churches, surrounding the audience, strengthens the link between the individual and the community. The loss of high frequencies and the resulting impossibility of localising the sound makes the believer part of a world of sound. He does not face the sound in "enjoyment" - he is wrapped up by it." (Schafer 1977 Pg118)

These practical examples can be visualised with sound waves that comprise of the compressions/condensations and the rarefactions/dilations of waves that look like hills and valleys. Ball describes this process as a comparison to the waves on the sea surface:

"the vibrations of air are not undulations in height; they are changes in the air's density. At the 'peaks' of sound waves, the air is compressed to greater density than it would be in a soundless space; at the 'trough's', the air is less dense (rarefied)." (Ball 2010 Pg35)

Helmholtz highlights the nature of waves neutralising or destroying one another when two condensations or dilations are added together (Helmholtz 1954 Pg53). This neutralising characteristic of waves and the occurrence of sympathetic resonance are aspects of vibrating waves that have been considered as part of this research. Other concepts considered include the perceptions of sound phenomenon such as intensity, where a louder note sounds for longer, where a higher note sounds louder than a low one and the duration of a note affecting the perception of its strength (Schafer 1977 Pg125).

These properties of sound waves (intensity, duration, volume and sympathetic resonance), together with the experiences captured through the phenomenological enquiry have led to a concept of the pure ratios used in PT forming a sense of assimilation. They are frequencies that you can gradually align yourself to when allowing yourself to be absorbed into these characteristics. This idea of pure ratios being assimilation frequencies has prompted a range of questions that would require further research in a physics setting such as the differences, if any, in the qualities of pure ratio waves compared to mixed waves. How do they impact on one another? How are sound waves absorbed in the body supplementary to being heard? For example, do they reach the body and ear at the same time? Are they absorbed by the skin or do they
penetrate other organs, and under what conditions? How are waves generated by the body affected by sound waves introduced externally?

Whilst some of these questions may have been answered from a medical and scientific perspective (considering the use of ultrasound in medical imaging as an example) they seem to not have been considered in connection with the nature of sound, particularly with regards to temperament and its phenomenology.

Visual Sound

The contemplation of sound physics prompts inquiry of the same frequencies experienced visually, perceived as colour. This is significant to this research considering the range of historical inventions that aimed to capture sound visually. For the purposes of this study, researching the frequencies of colours prompted questions such as: Is there a musical scale that aligns to the colour frequencies of the rainbow, and are those frequencies in pure ratios?

Do visual artists use colour charts (such as RGB or CMYK) with consideration of their frequencies and 3/2 or other ratios as a guide for their relationships to one another? Has there been a historical evolution of colour and frequencies much the same as there has been for sound, it’s ratios and subsequent temperaments?

In the late 1660’s Isaac Newton, through his exploration of the colours in the rainbow, considered seven divisions that aligned to the seven notes of the musical scale (Ball 2010 Pg41). It is however, unclear and unlikely that this involved precise frequency analysis, as the Siren that could measure periodicity wasn’t invented until 1819.

Throughout the 1800’s there were many composers that experimented with the relationship between sound and colour including Berlioz, Debussy, Scriabin, Rimsky-Korsakov and Wagner. The majority of studies find some alignment between frequencies in the musical scale and specific colours. The Rosicrucian Order based their theories on Just intonation suggesting relationships between note names, frequencies, and colours. Charles Fourier in Theorie de l'Unite Universelle 1846 takes this connection further, linking the connection between colours, note names and metals (States 2014).

Helmholtz also covers a comparison of light and sound frequencies, however states that the “confirmation only succeeds within certain limits” continuing to explain that; “no kind of coloured light exists which can give us the sensation of a single one of the fundamental colours with exclusive purity” and are therefore “unable to show objectively the absolutely pure fundamental colours.” (Helmholtz 1954 Pg90).

In more recent times, studies have included the work of Neuro-marketing expert Professor Diana Derval outlining that 25% of the population perceive colour as dichromats (less than 20 colour nuances). 50% of the population are trichromats, and the remaining 25% tetrachromats, perceiving up to 39 colour nuances (Derval 2015). A study that aligns the JND of sound, approximately 36 divisions of an octave and these groups of colour perceptions would be a fascinating undertaking. An extreme example of experimentation with sound and colour is the colourblind avant garde artist Neil
Harbisson who in 2004, had an antenna inserted in his skull to use audible vibrations to perceive sound as colour (Contributors 2014). It would be interesting to extend experiments such as these to differentiate between frequencies that involve pure ratios and those that don’t.

Overall, the understanding of sound, colour, frequencies and their phenomenology seems largely under investigated. This is perhaps best articulated by Ball who outlines the many artists who have chosen to use only a minimalist approach to colour selection such as; Mondrian, Kasimir Malevich, Yves Klein and Franz Kline. Ball links this to our musical preferences with the idea that “the point is not necessarily which notes we choose but the fact that we choose them at all.” (Ball 2010 Pg34)

What is undeniable, and of interest to this study, is the full spectrum of sound and colour available to be consumed. Helmholtz described this as:

“Every individual partial tone exists in the compound musical tone produced by a single musical instrument, just as truly, and in the same sense, as the different colours of the rainbow exist in the white light proceeding from the sun or any other luminous body.” (Helmholtz 1954 Pg74)

Mathematics of Natural Frequencies

The mathematical understanding provided in this section focusses on the relationship between pure ratios and their corresponding frequencies. To support the phenomenological enquiry of the PT system, this research specifically sought to understand 3 mathematical aims.

Mathematical aims:

1. How the mathematical principles of PT apply to frequencies in music
2. How these PT frequencies, related to other frequencies in nature and the modern world
3. How a pure mathematical understanding of the frequencies may be impacted by external or contextual elements such as instruments, environment and practical performance aspects.

Achieving the first aim; developing an understanding of the relationship of the pure ratios and their frequencies was more complex than originally anticipated. It was difficult to find a definitive list of Pythagorean frequencies as they vary depending on the fundamental frequency that the calculations are being made from.

Throughout the study a number of cross checking activities to practical applications of PT also provided a range of outcomes. These included, tuning apps that have PT settings, online resources, a digital piano, logic studio software and PT tuning forks.
<table>
<thead>
<tr>
<th>Pitch</th>
<th>Cleartune app</th>
<th>Tuning BLOG¹</th>
<th>Tuning Forks</th>
<th>Yamaha Digital Piano</th>
<th>Logic Software</th>
</tr>
</thead>
<tbody>
<tr>
<td>C4</td>
<td>256</td>
<td>256</td>
<td>258</td>
<td>258</td>
<td>256</td>
</tr>
<tr>
<td>C#4/Db4</td>
<td>273.4</td>
<td>270</td>
<td></td>
<td>273.375</td>
<td></td>
</tr>
<tr>
<td>D4</td>
<td>288</td>
<td>288</td>
<td>290</td>
<td>290</td>
<td>288</td>
</tr>
<tr>
<td>D#4/Eb4</td>
<td>303.4</td>
<td>303</td>
<td></td>
<td>303.407407</td>
<td></td>
</tr>
<tr>
<td>E4</td>
<td>324</td>
<td>324</td>
<td>322</td>
<td>333</td>
<td>324</td>
</tr>
<tr>
<td>F4</td>
<td>341.3</td>
<td>341</td>
<td>344</td>
<td>344</td>
<td>341.333333</td>
</tr>
<tr>
<td>F#4/Gb4</td>
<td>364.5</td>
<td>364</td>
<td></td>
<td>364.5</td>
<td></td>
</tr>
<tr>
<td>G4</td>
<td>384</td>
<td>384</td>
<td>376-387</td>
<td>387-398</td>
<td>384</td>
</tr>
<tr>
<td>G#4/Ab4</td>
<td>410.1</td>
<td>405</td>
<td></td>
<td>410.0625</td>
<td></td>
</tr>
<tr>
<td>A4</td>
<td>432</td>
<td>432</td>
<td>430</td>
<td>441</td>
<td>432</td>
</tr>
<tr>
<td>A#4/Bb4</td>
<td>455.1</td>
<td>455</td>
<td></td>
<td>455.111111</td>
<td></td>
</tr>
<tr>
<td>B4</td>
<td>486</td>
<td>486</td>
<td>484</td>
<td>495</td>
<td>486</td>
</tr>
<tr>
<td>C5</td>
<td>512</td>
<td>512</td>
<td>506 - 516</td>
<td>527</td>
<td>512</td>
</tr>
</tbody>
</table>

Figure 1 - Pythagorean frequencies across devices

As the table demonstrates, the fundamental frequency seemed to vary, as did the results which were due largely to using spectral analysis which, depending on the software used and the precision of the cursor on the Fast Fourier Transform (FFT) analysis visual, can vary. Both Yamaha and Logic were contacted during the course of the research to enable an understanding of their approach to scale generation, however neither replied to the request for information.²

These challenges were compounded by the wide range of terms used to discuss the same content across the disciplines (music, mathematics, physics). Reviewing materials across these disciplines (written over many centuries) used mixed terminology including: frequencies, hertz, ratios, logarithmic conversions, cents, combinations of tones and semitones and the number of commas combining a tone, intervals and/or octaves.

The second aim in the mathematical understanding to support this research was developing a comprehensive list of frequencies in nature and the modern world to look for similar patterns of the Pythagorean pure ratios. This was prompted by unverified sentiments such as “dolphins and whales align to 424 and 432” and “the great pyramid resonates at 280 and 440” and a general view that PT is more aligned to nature due to the 3/2 ratio’s connection to DNA and the natural world.

A comprehensive list of these frequencies would provide an understanding on the relationships across nature, technology, music and human physicality, however, the

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² The following summary has been included post examination as it was provided by one of the examiners: The Pythagorean Tuning provided with Logic X, consists of a chain of 3/2 Perfect 5ths, which stretch from Eb to G#. That is, it goes down 3 Perfect 5ths from C, and up 8 Perfect 5ths. This scale produces 11 Major triads, which either have M3rds of 408 or 386 cents (roughly) and minor 3rds of 316 or 294 cents (roughly), filling out a Perfect 5⁰ of 702 cents (roughly).
sources found throughout this research were largely incomplete, unreferenced and unreliable.

The third aim, to review a pure mathematical understanding of the pure ratios and how they relate to the frequencies in both PT and ET is provided as follows:

Using the string analogy that was favoured by the Pythagoreans and their use of the monochord we understand that the interval of an octave has a ratio of 1/1, it is a doubling of the frequency, or if you were to pluck a string at the midpoint you would sound a note one octave higher (as shorter string lengths produce higher notes). The Pythagorean ratios for the diatonic scale are C (1/1), D (9/8), E (81/64), F (4/3), G (3/2), A (27/16), B (243/128) and the Octave (2/1). To determine each ratio mathematically, each note is multiplied by the 3/2 ratio, or in musical terms, ascends or descends by a pure fifth.

To determine the resultant frequencies to work with for this study, a frequency conversion map was required. I developed the following table that auto generates the frequencies for different fundamental frequencies so as to test the information that I was finding across conflicting resources. Each cell takes the previous frequency in the scale and divides the frequency by the bottom aspect of the ratio and multiplies by the top. For example, to determine the frequency of A4; the table divides C4 (256) by 16 and multiplies by 27 to deliver the frequency 432. When a new fundamental frequency is entered at C0 the table auto generates in alignment with the Pythagorean ratios. For example, to achieve A=440, the C0 fundamental frequency would be 16.2962963.

<table>
<thead>
<tr>
<th>PT Ratio</th>
<th>OCTAVE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td>A4</td>
<td>256</td>
</tr>
<tr>
<td>A4</td>
<td>256/3</td>
</tr>
<tr>
<td>A4</td>
<td>256/9</td>
</tr>
</tbody>
</table>

*Figure 2 - Automated Pythagorean frequency table*
When establishing an equivalent table for ET, I observed that the difference between the frequencies were not equal. From this, I discovered that ET requires a Logarithmic equation to achieve the equal divisions:

\[ \log_2 r = \frac{x}{1200} \Rightarrow 1200 \log_2 r = x \Rightarrow 1200 \left( \frac{\log_{10} r}{\log_{10} 2} \right) = x \Rightarrow 3986.3137 \times \log_{10} r \approx x \]

(Smoyer 2005)

Logarithmic scales are used when there is a complex, nonlinear, large range of quantities. The premise is based on orders of magnitude, rather than a standard linear scale. The logarithmic equation provides us with 12 equal divisions in the octave in the unit of cents. There are 1200 cents in an octave and each semitone is 100 cents. Like many musicians, I had assumed there was a direct correlation between cents and hertz (frequency). To test this assumption, I asked others what they thought the relationship for hertz and cents was on social media. A well-established music producer responded with:

“100 like in a semitone. Although, when talking in Hertz, you might say 41.2 Hertz, not 41 hertz 20 cents. I’ve never heard cents mentioned when talking Hertz.” (facebook:25092014)

The origin of the logarithmic scale for ET was developed by Gaspard de Prony in the 1830s. It was subsequently included in Hermann von Helmholtz’s On the Sensations of Tone when Alexander J. Ellis translated, annotated and included additional theories in the 1885 publication. Specifically, the publication notes say: “Translated, thoroughly Revised and Corrected”.

Whilst mathematically the logarithmic equation is a neat way of representing the 12 equal divisions of the octave (\( \sqrt[12]{2} \)) I have not through this study found any value in working with cents. The complexity of the logarithmic equation has added a layer of confusion to understanding what the frequencies are and how they relate to one another in music. The complexity has made frequency analysis incomparable across technology platforms especially when fine editing in music software applications. Beament further attests this sentiment:

"For that reason I never use the so-called unit of pitch, the cent, which is a unit of frequency and not of pitch. It gives a completely false impression of how accurately we can hear any pitch. I am sure it has caused anxiety amongst musicians because it suggests that they ought to be able to hear pitches far better than they can. We cannot hear even a pure tone to better than 10 cents over most of the range of pitch frequencies used in music." (Beament 2003 Pg71)

Wood holds a differing view demonstrating that his understanding of intonation is from a mathematical perspective. He finds that working with only with the ratios limits our ability to measure their relative size. The ratios only provide an order of magnitude for the intervals, meaning that we have to multiply the corresponding ratios, to achieve a
relative perspective, which can much easier be achieved though the cent measurement \textit{(Wood and Bowsher 1980 Pg52)}.

\section*{Naturally Occurring Harmonics}

The other mathematical consideration relevant to this study is the overtone series. Overtones are naturally occurring harmonics that are audible when any complex tone is created (i.e. excluding pure sine waves). Ball highlights that these are generally whole number multiples of the fundamental \textit{(Ball 2010 Pg63)}. It is the overtone series that provides timbre, which is essentially the different colourings that we hear in a voice or instrument. The beginning of the overtone series features prominently in every tone, and varies more significantly in the upper partials providing the various instruments with their unique timbres. Duffin accounts that the harmonic series is an infinite number of overtones that continue beyond the range of human hearing \textit{(Duffin 2008 Pg22)}. The overtone series is important to this research as it is the only aspect in music that is unchangeable, as highlighted in the following quote from the Reimer and Wright book, \textit{On the Nature of Musical Experience}:

\begin{quote}
“Bernstein hypothesized that "all music - whether folk, pop, symphonic, modal, tonal, atonal, polytonal, microtonal, well-tempered or ill-tempered, music from the distant past or the imminent future - all of it has a common origin in the universal phenomenon of the harmonic series.” (Reimer and Wright 1992 Pg20)
\end{quote}

The table below is provided to show the equivalence of overtones, harmonics, their interval relationship and an example in PT providing the frequency and note equivalent. It is important to note that three of the PT pitches sound higher than they would naturally resonate as an overtone. This occurrence is more pronounced when applying the harmonic series to ET where only the fundamental and subsequent octaves are aligned. All other frequencies in the tempered scale do not align to the naturally occurring harmonics.

\begin{table}[h]
\centering
\begin{tabular}{|l|l|l|l|}
\hline
\textbf{Fundamental} & \textbf{1st harmonic} & \textbf{Fundamental} & \textbf{54 Hertz} \\
\hline
\textbf{1st Overtone} & \textbf{2nd Harmonic} & \textbf{Octave Above} & \textbf{108 Hertz} \\
\hline
\textbf{2nd Overtone} & \textbf{3rd Harmonic} & \textbf{5th Above Octave} & \textbf{162 Hertz} \\
\hline
\textbf{3rd Overtone} & \textbf{4th Harmonic} & \textbf{2nd Octave} & \textbf{216 Hertz} \\
\hline
\textbf{4th Overtone} & \textbf{5th Harmonic} & \textbf{3rd Above 2nd Octave} & \textbf{270 Hertz} \\
\hline
\textbf{5th Overtone} & \textbf{6th Harmonic} & \textbf{5th Above 2nd Octave} & \textbf{324 Hertz} \\
\hline
\textbf{6th Overtone} & \textbf{7th Harmonic} & \textbf{Minor 7th above 2nd Octave} & \textbf{378 Hertz} \\
\hline
\textbf{7th Overtone} & \textbf{8th Harmonic} & \textbf{3rd Octave} & \textbf{432 Hertz} \\
\hline
\textbf{8th Overtone} & \textbf{9th Harmonic} & \textbf{Whole tone above 3rd Octave} & \textbf{486 Hertz} \\
\hline
\textbf{9th Overtone} & \textbf{10th Harmonic} & \textbf{3rd above 3rd Octave} & \textbf{540 Hertz} \\
\hline
\end{tabular}
\caption{Overtone alignment table}
\end{table}

It is not just the tempering of scales that produce this misalignment of harmonics, Ball outlines that percussive instruments in particular contain inharmonic overtones that create ambiguous pitch, resulting in their unique timbral effects \textit{(Ball 2010 Pg231)}. For
the purpose of this research, it is significant to acknowledge the dissonances created by
naturally occurring phenomena and to consider these as timbral benefits not as
mathematical mistakes.

Understanding Temperament or Tuning

I first selected PT for this research topic as it was largely referred to as the original,
pure, harmonically aligned diatonic scale. However, early in this research I was
prompted by the literature review to consider the difference between temperament and
intonation.

According to Doty, Just Intonation is any tuning system that is built on whole number
ratios, he does however continue that it has a “strongly implied preference for the
simplest ratios” (Doty 2002 Pg1). Throughout the literature review, I observed that PT
is often referred to as Just or as the first Just Tuning System. However, from a
mathematical perspective references clearly highlight how they are distinctly different.
Doty refers to PT as a Pythagorean Framework that is a subset of Just Intonation (Doty
2002 Pg3). The table below highlights where the two systems differentiate with simpler
Just ratios for the 3rd, 6th and 7th. The idea of these intervals having consonant ratios is
credited to the English monk Walter Odington (c. 1300) (Doty 2002 Pg3). However, it
can largely be assumed that there were others between Pythagoras, such as Ptolemy,
that were already exploring variations of Just intervals. According to Helmholtz, “the
proper intonation of major thirds” was not in use until the end of the Middle Ages, (the
1500’s) the Pythagorean 81/64 prevailed until this time (Helmholtz 1954 Pg90).

<table>
<thead>
<tr>
<th>Interval</th>
<th>Pythagorean Ratio</th>
<th>Just Intonation Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unison</td>
<td>1/1</td>
<td>1/1</td>
</tr>
<tr>
<td>Second</td>
<td>9/8</td>
<td>9/8</td>
</tr>
<tr>
<td>Third</td>
<td>81/64</td>
<td>5/4</td>
</tr>
<tr>
<td>Fourth</td>
<td>4/3</td>
<td>4/3</td>
</tr>
<tr>
<td>Fifth</td>
<td>3/2</td>
<td>3/2</td>
</tr>
<tr>
<td>Sixth</td>
<td>27/16</td>
<td>5/3</td>
</tr>
<tr>
<td>Seventh</td>
<td>243/128</td>
<td>15/8</td>
</tr>
<tr>
<td>Octave</td>
<td>2/1</td>
<td>2/1</td>
</tr>
</tbody>
</table>

Figure 4 - Pythagorean and Just interval ratios

In this section, we have explored the physics of sound and the mathematics of
temperament, including the natural phenomenon of the harmonic series and we have
considered the difference of pure intonation and temperament. We haven’t considered,
how these frequency differences in the western musical scale are heard. There are two
concepts that are relevant to this study that are worth exploring, one is the idea of beats
that occur in tempered scales and the other is known as Just Noticeable Difference or
(JND).
Frequency Perception

According to Jorgensen, the idea of beat counting was first discovered in 1749 by Robert Smith (Jorgensen 1991 Pg3). Ball describes the beating phenomenon as waves interfering when two pure tones are played simultaneously. As he provides, this understanding of frequencies reinforcing and then cancelling each other out can be described as “a periodic rise and fall in loudness superimposed on the two notes, called beating” (Ball 2010 Pg168). The beating process is predominantly used to assist tuning instruments, such as pianos. Due to the speed of the beats varying over pitches, they get faster as the frequencies are further apart, providing a way to discern the precise tuning of the pitches. On the experience of using beats to tune pitches, Duffin provides:

“the major third of ET is so far out of tune that you can barely count the beats. Beating at nearly twelve times the speed of the fifth, it positively jangles”. (Duffin 2008 Pg30)

Plomp highlights in his book, Aspects of Tone Sensation, that similar to combination tones, the beating sensation underwent extensive experimentation in the 1900’s but was thought to be “incompatible with Ohm’s acoustical law”. He also provides that Bosanquet (1881) referred to beating frequencies as “mistuned consonances” (Plomp 1976 Pg42).

Pierce refers to the JND concept as a psychoacoustics measurement and refers to it by its more accurate term Limen (Pierce 1983 Pg130) which is defined by Google Dictionary as: “a threshold below which a stimulus is not perceived or is not distinguished from another”. JND is most commonly referred to in the cents measurement for consistency, as it varies relative to the frequencies being measured if in hertz. Plomp outlines the 1967 JND study undertaken by Ritsma which found that the “frequencies dominant in pitch sensation vary significantly from subject to subject” (Plomp 1976 Pg117). Usually however, JND is somewhere in the range of five to fifteen cents depending on the scenario and individual.

There are online ways of testing pitch perception, one such example is tonometric.com, which provides two tones around 500 Hz (Mandell). At this frequency, semitones are separated by approximately 30 Hz. With the conditions of this test, the site equates perception of less than .75 hertz as exceptional, less than 1.5 hertz as very good, less than six hertz as normal, less than 12 hertz as low-normal and greater than 16 hertz as a possible pitch perception deficit.

Audiocheck.net is another site that provides a pitch perception test at 50, 20, 10, 5, 2 and 1 cent differences (Pigeon 2009). Using this test, I was very comfortable discerning pitch differences at ten cents wide, somewhat reliable at five cents wide and at two cents wide was only successful 50% of the time. This is significant to the practice led components of this study where I would often adjust the pitch of a note by 1 or 2 cents purely to affect a timbral change.

In a practical scenario, the pitch ranges that we perceive vary more significantly than the software generated tests due to a range of timbral and environmental attributes. Pierce highlights examples where musicians in a string trio were more than 18 cents
away from the true frequency at least half the time, and the greatest differences exceeded 40 cents (Pierce 1983 Pg132). Helmholtz describes the link between the functioning of the cochlea and how this translates into our perception of cents:

“According to Waldeyer there are about 4500 outer arch fibres in the human cochlea. If we deduct 300 for the simple tones which lie beyond musical limits, and cannot have their pitch perfectly apprehended, there remain 4200 for the seven octaves of musical instruments, that is, 600 for every Octave, 50 for every Semitone (that is, 1 for every 2 cents).” (Helmholtz 1954 Pg147)

The mathematical understanding of frequencies that I have developed as part of this study led me to question whether the benefit of a pure ratio needed to be exact or whether benefits are reached being closer to the pure interval. I also contemplated the idea that every room and object (naturally occurring or otherwise), has a natural resonance. I considered practical applications of how to match that resonance to amplify the sound and experience. This avenue of enquiry prompts further research questions such as; how do you determine the natural frequency of a person (and individual organs)? Are frequencies comparable across individuals and if so how? Does your fundamental frequency change on different days? Can inherent frequencies be enhanced by other natural resonances occurring in the environment? And finally, therefore, what is the phenomenology of experiencing notes or frequencies that correlate to your inherent resonance?

The following description of wave behaviour provided by Pierce inspires many more questions on the nature of sound waves, especially on the unseen impacts and potential benefits of waves that are resonating as pure ratios:

“We have all seen the circles of ripples that move outward when a raindrop falls into a quiet pool, or when we drop a pebble into smooth water. In a similar way, a disturbance of the air moves out from the disturbing source. However, sound waves do not travel on a surface, but through the air in all directions. The air in a sound wave does not move bodily, as water flows in a stream, but only locally. One part of the air imparts motion to that ahead, as might happen if, in a long line of closely spaced people, a person at the end gave a push to the one ahead, and that one, in turn, pushed the next. We can imagine a disturbance traveling to the head of the line without anyone taking a step forward. We all experience sound in the air, but we can't see sound waves.” (Pierce 1983 Pg25)
Chapter 2 – Aims and Scope of Research

Aims of Research

The background information provided so far demonstrates the complexities of this topic and its coverage across many specialist disciplines. In commencing this study, I considered the areas which I required a basic awareness of to position an experiential exploration of PT in Practice led research. I am not a mathematician, physicist, music historian, music theory specialist, nor composer, music engineer or professional producer. I am however, a professional singer who is a specialist in the awareness of self in performance, presence and mindfulness. This includes a focus on the holistic experience of artistry and audience interaction.

Approaching this research with these skills provides a unique perspective to the application of PT for music creators and consumers, and provides an original contribution to knowledge in this field. The avenue of enquiry selected, which is grounded in self-awareness naturally lends itself to a phenomenological research approach. This avenue of enquiry also leads to findings that are more qualitative in nature, than quantitative. The collection process for capturing insights evolved significantly over the research period. This resulted in a number of recommendations for how further research could benefit from these initial findings leading to the ability for quantitative studies with further depth in collecting and categorising of experiences related to Pythagorean Tuning.

Prior to commencing the study, I captured two aims in the research diary. Firstly; an aspiration for the study to be relevant to the real world, that is to say that it has practical and meaningful application. Examples of how this may look in practice would be the further development in both artistic and commercial avenues where Pythagorean Tuning is not only applied, but there is an understanding of why it is being applied and the potential benefits of its use. The second aim was for the research to be evidence based, meaning that there is traceability from the data collected to the outcomes perceived. Whilst both of these aims have been met through the research activities, my definition of what evidence based means has shifted from working with a phenomenological approach. For example, my skill base has differed significantly to the collaborators that have participated in the study. As a result, what I aimed to be evidence based, such as a validation of the experiences I had captured, varied considerably due to the individuality of the participants and their own areas of interest.

When first contemplating this study, the main research question was; why and how did ET become the international tuning standard in 1939? Throughout the study however, particularly through the literature review, the aspects of society, evolution, technology and so many other contextual elements have exposed the complexity of how we got to this point. Furthermore, this study has exposed how much we don’t know and haven’t explored. This has led to the fundamental research question: What is the experience of PT when applied to new music?

Early in the research I explored the concept of inherent tuning, making observations on the comparisons between PT, ET and Just Intonation. The intent once the creative
components were completed, was to provide samples of the music in each of the three tunings and survey audiences for their observations. This approach was revised as two learnings eventuated: firstly, that audiences were generally unable to discern the differences between the tuning systems and secondly, that as a vocal artist whilst a backing may be able to be changed with ease using DAW’s a vocal would need to be completely re-recorded in each (thus introducing an unknown variable to the comparison through performance variation).

In some areas relating to Pythagorean Tuning, there is exceptional depth in what has been researched, such as through the Helmholtz era, exploring the phenomena of sound including perception, combination tones, beats and cancelling wave forms. However, this avenue of enquiry focussed predominantly on the hearing of sound and not a holistic experience of sound. Likewise, there is a plethora of material that is consistent in protestations of the power of music; how it is beneficial for the soul with its alignment to nature. These materials however, lack any depth of analysis on why or how these benefits can be leveraged with practical application. It is an aim of this research to unravel some of these assertions and provide meaningful ways in which the benefits of natural tuning can be applied.

In-line with this intent, much of the insightful, thought provoking concepts considered throughout this research have occurred in discussions with individuals trying to understand the research topic. Each time I would introduce someone to the research they would feedback a distinct understanding of something they have heard a sliver of information on that is generally part of a much broader misunderstood whole.

To achieve the aims of this research, I have found the Ladder of Inference to be a beneficial model to consider how and why we are where we are with regards to temperament. The ladder encourages people to consider what pool of data they have at their disposal to which they then add meaning, leading to assumptions, then conclusions which are the basis for forming beliefs and ultimately taking actions based on these beliefs (Argyris 1990). When applied to the paradigm of natural tuning, we can see that the pool of data is vast (philosophy, mathematics, physics, inherent experiences, evolving technologies). From this, society draws only parts of the information, and after progressing through the ladder (over two millennia) take actions; like adopting a very narrow tuning option such as ET in an effort to simplify and standardise a very complex multi-discipline field.

With these considerations and the findings of this research I am mindful of how this study period has transformed many aspects of my life. The way in which I view the validity of previous research and available content, the way I view the role of research in evolving society, the way I analyse, explore and contribute original thinking have all significantly shifted. My sense of self, artistic expression and aspirations and personal purpose have all solidified during the study period. Fundamentally, the quickening that has occurred in how I create a space for these reflections and growth have undermined my role as a songwriter, where I am aware that I am transforming so quickly as a person that songs I have written lose relevance for me, almost as instantaneously as they have been written. This has led to a significant shift in my compositional style throughout the project.
Due to these personal developments, it has been difficult to discern whether the research findings can be attributed to working with the Pythagorean frequencies or to what extent they are a result of being immersed in a philosophical, phenomenological enquiry activity.

**Phenomenological Enquiry**

Phenomenology as a research method has only been in practice in the last 50 years, which, considering ET became the tuning standard 78 years ago it is unlikely that a study of this composition has been completed. Through extensive research, I have not uncovered a similar undertaking, hence making this phenomenological study a new contribution to the field.

Reimar and Wright confirm that Phenomenology as a research method provides for descriptive capturing of experiences that can be analysed for further philosophical investigation. They provide that the ultimate destination is an exploration of all “fulfillable possibilities” (Reimer and Wright 1992 Pg52). This is further attested in the book *Practice as research: approaches to creative arts enquiry* by Barrett and Bolt who claim the limitations of qualitative research when realising “how much life was squeezed out of human experience when we attempted to make sense of it in a numeric, non-contextual way” (Barrett and Bolt 2007 Pg149).

In the book *Phenomenological Research Methods*, Moustakas highlights the importance of enquiry that is open and newly approached, not bound by customs, beliefs and prejudices (Moustakas 1994 Pg41). In this regard, I have used the Ladder of Inference to consider the assumptions, beliefs, experiences and actions that have led us to our current understanding of temperament.

Whilst an initial aim was for evidence based research, it is acknowledged that evidence can take many forms. At one end of the spectrum there is statistically significant driven research and at the other, an opening of the possibilities of experience. Barrett and Bolt provide a similar ethos, noting the growing recognition in the scientific community that only pursuing what can be exactly measured has limitations that could be addressed through a range of complimentary research methods (Barrett and Bolt 2007 Pg4).

A complimentary research method which has been used in this study is Ethnographic Research. This approach is the cross validation of research materials including photos, recordings, conversations and observations providing a richer understanding of the themes in the research. Moustakas discusses a similar concept with the idea of Horizontalisation where all of the inputs are treated equally, and it is not until a process of categorisation is complete that themes emerge (Moustakas 1994 Pg97).

Both of these approaches have been utilised throughout this study, through the capturing, coding and analysing of diary entries. They have been valuable, as there has been a strong focus on the practice component of the phenomenon, mainly in writing and playing on a digital and acoustic piano tuned in PT. Simple techniques such as capturing short observations on post-it notes whilst practicing, composing, recording and mixing have led to a wealth of observations to draw meaning from. Barrett and Bolt refer to this type of research as “ongoing and persistent” further providing that this is
not a process of thinking to resolution, rather that it occurs naturally through the practice process (Barrett and Bolt 2007 Pg147). Within this study the ongoing and persistent nature of enquiry has led to personal transformation artistically and the ability to package this understanding into methodology for future studies and practice.

Whilst the practice led components have been supplemented by the literature review, one approach could not be completed without the other. An Oxford music professor asserts:

“strictly speaking you cannot write about music; music expresses what it has to say in its own terms, and you cannot translate these into language any more than you can translate a picture.” (Ball 2010 Pg382)

The approach to writing about musical experience has been challenging in this research, as the difference between ET and PT is subtle. The phenomenological approach has enabled the study to capture everything without judgement or categorisation. By not trying to form a description of the PT experience, the phenomenology has been captured in this research as; what are the conditions that create a PT experience? and; what can be experienced in the space that is created by these conditions? Ball further outlines the approach that other philosophers have taken to finding language for musical experience:

"Might there be a mode of emotionality inherent to music for which, as Aaron Copland put it, 'there exists no adequate word in any language', and which American philosopher Diana Raffman calls ineffable? Another philosopher, Susanne Langer, agrees with Copland that music may induce emotional states that have a quality of their own, for which we have no suitable vocabulary. Her stimulating idea, proposed in the 1950's is that music doesn't so much represent emotion as mimic it: the ebb and flow of music is analogous to the dynamics of emotion itself. As the American psychologist Carroll C. Pratt put it in 1931, 'music sounds the way emotions feel’”. (Ball 2010 Pg262)

Scope

The scope of this research covers two contextual and two experiential topics. The contextual topics include; an overview of relevant history and an understanding of frequencies. The two experiential topics include; what is the experience of PT and based on this, what are the existing and potential applications for its use. For each of these topics a clear definition of what is in and out of scope was required.

For the historical account, in scope includes; who was Pythagoras and the beliefs of the Pythagoreans. It also includes a timeline of significant events since this time including technology advancements and influences in society. A full historical account is out of scope, particularly regarding all tuning systems between Pythagorean and Equal Tempered. Also out of scope, is speculation on Pythagorean philosophy.

Regarding the understanding of frequencies, in scope topics include; basic physics of sound, visual and audible wave forms, and an overview of mathematical principles of ET and PT. How sound is created, what is music versus sound, psycho-acoustics and in-
depth analysis of mathematical formulas for temperaments are all out of scope.

The experiential scope is less defined as limiting this area of exploration would contradict the premise of phenomenological enquiry. However, broadly the scope includes; hearing, holistic physicality and mental and emotional responses to PT. It also includes the idea of inherent tuning (a pre-existing preference), as a way of considering experiences that are aligned to, due to, or in contrast to PT. In the practice led section the content considers how PT can be enhanced through composition and production and vice versa, how the compositional and production process is enhanced by working with PT.

Experiential topics outside the scope of this study include; cognitive analysis, how we hear and psychological models for considering experiences. In a more practical sense, out of scope considerations include sound quality such as engineering and acoustical considerations and cross analysis of tonality and temperament. Whilst these topics are touched on to support this study, they form broader topics that could constitute further areas of research.

How we experience PT is very much related to how it is applied. Therefore, applications of PT are explored, including; the application of PT to various instruments, benefits and challenges of working with and experiencing PT. Applications of PT also include; examples of PT in use and considering standards, consistency and accessibility.

When considering that frequencies are not limited to sound and music, the applications for Pythagorean frequencies could be numerous. As such, out of scope consideration of applications involves any non-musical applications, for example in the healthcare industry. It also excludes in depth recommendations for music software development which again, could constitute a further area of research. Finally, as this thesis explores the application of PT to the creation of new music, accounts of authentic performance (performing historical works in their original tuning) is also considered out of scope.

As this study focuses on creative experiences, it does not cover analysis of works created by other artists who have created works in PT. Whilst many works by other artists were reviewed throughout the study, detailed analysis of their experiences was removed from the scope early in the project design. Whilst providing this comparative analysis between the observations captured in this study and other artists would have been valuable, it soon became apparent that contacting and involving these artists as well as the collaborators for the producer project would not have been achievable within the research period.

The summary of findings also does not provide compositional analysis of the works created as part of this study as the study aims relate to phenomenological enquiry rather than theoretical compositional practice. As such, lead sheets or similar compositional devices that were used as a basis for the creative works have not been included in this paper as the production approach took the works beyond the original scores. This process of experimenting with PT sounds through the production process is one of the key features of this study.
Relevance of this Research

The relevance of this research is linked to recent shifts in modern society where there is increased holistic awareness of self and wholesome life choices. Practices such as mindfulness, and looking for healthier, more natural alternatives to the modern way of living have proliferated throughout mainstream media and consumerism. With this shift in mindset and behaviours, this research explores what the equivalent is in the creation of new music. Questions include; Does working with pure ratios and natural tuning provide a beneficial musical experience? If creating a more holistic life and sense of self, are there frequencies that are inherent to humans that could be leveraged through music to enhance self-awareness? Are these frequencies the pure ratios used by the Pythagoreans?

The rate of change has been evident throughout the literature review where the publishing date has played a significant role in how the information has contributed to this study. This has especially been with regards to electronic capabilities, societal evolutions and perceptions of temperament along the timeline.

ET has normalised in modern society, especially in the last 50 years, and yet musical genres have changed so considerably in this time. In the 1800’s, there was an exploration of temperaments, now the exploration is with technologies. The technological developments, however, are devoid of discussion of alternate tuning selections, their experience and benefits. We have accepted the tuning status quo at a time where the accelerated development of technologies to experiment and explore frequencies in music is evolving at an unprecedented rate.

The quickening of technological advancements is occurring at all levels from new hardware being developed to minor software enhancements. This environment provides an opportunity for this type of research as it can assist to drive the direction of such developments. A practical example of how a minor software enhancement has been significant to this research is the release of the Flex Pitch development in the Logic Pro X DAW\(^3\) (released in July 2013). When commencing the practical component of this research, fine editing the vocal lines was time-consuming, limited and often inaccurate against the outcomes being sought.

The Flex Pitch functionality includes six fine edit controls including:
- Vibrato adjustment
- Fine pitch edits (in cents)
- Pitch Drift at start and end of note
- Formant shift
- Gain

The ability to fine edit in this way fundamentally changed the way I recorded and edited vocals on the later releases as part of this study. I was able to relax my vocal performance, knowing that I had greater control in the editing process. I was able to experiment with different timbres rather than trying to deliver an exact vocal take. I was also able to explore the experience of a perfectly tuned PT vocal track. In earlier

\(^3\) A DAW is a Digital Audio Workstation
recordings, this was limited by auto-tune plugin abilities to work with the global tuning settings to create a pseudo PT vocal experience. This example of technological changes has played a significant role in this research project and demonstrates the ongoing relevance of exploring natural tuning in the creation of new music.

**Process Practical**

To support the study aims and in particular the experiential nature of the studies undertaken, a strong project management approach was established early to ensure that the research objectives would be realised.

Due to the potential of scope creep on such a wide-ranging topic, core project management principles were introduced, such as:

- defining scope
- regular reporting on progress
- management to timelines, and
- anticipated resourcing and time allocation

This approach ensured that there was a balanced input of information to the final thesis, including:

- The primary researcher’s observations
- Experiences and insights of others discovered through the literature review
- Experiences of others captured through the practical collaborations
- Observations of others held through dialogues throughout the study period (i.e. conferences)

These inputs were captured and categorised through a database and reported on periodically to ensure each area of enquiry was being explored equally. Categories were first defined at a process level and then further assessed midway through the research, as themes of enquiry started to emerge. The categories included:

- Research (notes, quotes, ideas and questions)
- Reference materials (books, music, research papers, journals, software)
- Data (diary entries, response to study invitations, audience responses, inherent tuning preferences)
- Field of practitioners (musicians and researchers)

The themes included:

- History (Pythagoras, society, timeline)
- Frequencies (physics, colour, temperament, maths)
- Process (practical, analysis, further research, context)
- Experiences (inherent, physicality, environment, JND, hearing, tonality)
- Applications (instruments, benefits, miss-application, examples, conceptual)
Determining the practical components of the study was challenging as there were many potential performance aspects to explore. The first two years of study (leading into the confirmation seminar) involved applying PT in different settings to inform the design of the practical components. This included:

- Practicing and writing on a digital PT tuned piano
- Creating backing tracks for live performances in PT
- Performing live using the PT backing tracks and exploring the experience as a performer and observing the audience response
- Producing and releasing three Christmas Carols in PT
- Exploring, using a spectrograph, whether I was in fact singing in PT, and singing a Capella to explore what my inherent tuning may be
- Performing live across genres (classical, jazz and contemporary) with live instruments (piano, guitar, flute) in both ET and PT to explore the experience as performers and survey audience members on their responses to the tuning.

Each of these activities helped to define the scope of the practice led component by providing early findings. These findings informed the areas of enquiry that would benefit from a deep dive exploration. Each of these activities and the early findings are covered in the Summary of Findings section of this dissertation. From these, a decision was made to focus primarily on the recording process rather than live performance. This was partly due to advancements in technology which enabled the ability to capture and analyse the performances. Additionally, my observations in a studio setting throughout the early research activities found that being immersed in PT provided more significant observations than those in a live performance setting. I was keen to investigate whether the experiences of other producers were similar to mine. I was also keen to continue self-producing to further explore the early findings.

The producer project forms the main creative work submission. It involves working with diverse music producers from around the world to capture their experiences collaborating on a recording project using PT.

The producer project was inspired by the initial observations preparing the backing tracks in PT and also the creation of the three Christmas carols released in 2011 and 2012. The Christmas carols took the recording experience a step further by including vocals, which involves the process of layering, harmonies, editing and effects. The producer project expands on these experiences by exploring a wider range of genres and creating original compositions. Through the study it was envisaged that a number of practical and experiential observations would be made regarding the studio performance and recording process.

Producers by nature need to have highly honed and receptive skills in terms of their musical awareness. Producers are skilled in observing the finer details of a performance as everything recorded is under a microscope once it is captured in a Digital Audio Workstation (DAW). The purpose of recording with producers from around the world provided a diversity of experience in terms of the cultural and region-specific practices and trends in the recording space, including software, facilities and work environment. Producers have a highly tuned awareness of the subtleties of both the technical and experiential aspects of music through the recording process.
To work with the producers, ethics clearance was secured for the research project. Music producers were contacted via email or online and asked if they would like to participate in the study:

“Dear (producers name),

I am currently completing a PhD applying PT to the creation of new music. The study is exploring the impact of PT on creators and listeners. There is a short 3 minute video (linked) explaining the research.

The study involves producers from around the world each creating one track (any style) in PT and capturing their experiences, the track can be worked on at any time over the next year.

To participate, you would be required to produce 1 track (any style) in PT and capture your experiences.

There is more information on the research website including the Plain Language Statement for the study (linked). Please let me know if you would be interested in participating and we can discuss any questions you may have.

Sincerely, Mirra Jensen.”

Selecting Producers to contact occurred in a variety of ways. Initially, a list was created of the top charting tracks on itunes to identify who had produced them and their contact details. I also searched for lists of top producers online. Websites such as taxi, hitquarters and jmv, contained lists of this nature which were further supported by searching on LinkedIn and Wikipedia. Together these sources provided a list of 322 producers, of which, approximately half were contacted to participate. At least 15 of the list were deceased, many had moved on from music and contact details could not be located for the majority. Of those that did respond (approximately 20) the general response from management representatives was that due to scheduling and time commitments they would not be able to participate (email:06021):

“Thank you for your invitation to RedOne to participate in your study. Unfortunately, due to pressure of work, we won’t be able to find room to put this on RedOne's schedule. Thank you for thinking of us and good luck with your research.”

Two managers declined their artist’s participation due to funding expectations. A Hip-Hop producer replied simply with “No Thanks” (email:030214). However, representation for Australian artist Gotye provided a supportive response with (email:221113):

“Thanks for your email and interest in Gotye, I passed your request on for his consideration. Unfortunately, due to a very busy schedule of recording and touring planned for the next few years he has asked me to decline. He has asked me to pass on his best wishes for your project.”
Three producers who accepted the invitation from this process all withdrew, one was a Grammy nominated producer who participated for 20 months with 80 emails in collaboration and correspondence. Lack of time, focus and challenges with software compatibility all played a role in the collaborations that were not completed. The six producers that did participate were sourced in the following manner:

<table>
<thead>
<tr>
<th>IDENTIFIER</th>
<th>SOURCED THROUGH</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRODUCER #1</td>
<td>Contacted through a Xenharmonic facebook group</td>
</tr>
<tr>
<td>PRODUCER #2</td>
<td>Home visit to troubleshoot studio purchase</td>
</tr>
<tr>
<td>PRODUCER #3</td>
<td>Referred by mutual colleague</td>
</tr>
<tr>
<td>PRODUCER #4</td>
<td>Contacted via mutual colleague</td>
</tr>
<tr>
<td>PRODUCER #5</td>
<td>Referred by mutual colleague</td>
</tr>
<tr>
<td>PRODUCER #6</td>
<td>Contacted through a list of Xenharmonic producers</td>
</tr>
</tbody>
</table>

Midway through the Producer Project I considered a change in approach to record a live album of an improvised composition in PT working with other connected musicians. Whilst this idea was not pursued instead of the studio album, it is a recommended further area of research. The idea of live improvised composition in PT also influenced the way in which I recorded the studio album; tracks produced later in the process underwent less planning and structured composition. The recording approach evolved to being in the moment and singing with one take or singing words that were felt rather than following the written lyric.

The music producers participating in the study were asked to capture their experiences in the form of diary entries similar to those that I used to capture my experiences. They were provided with a template and encouraged to capture observations in a forensic manner. The template prompted participants to capture the influencing context of their experiences and the impact of the physical, technical, emotional and creative aspects of recording in PT. The templates were generally not populated and insights were captured through correspondence or by my being present in the sessions to document what was said. Some producers submitted a summary of their experiences following the project. Ideally, a detailed diary process would have provided greater depth of information, such as, specifically how PT was applied in their process. It is noted that in this study this depth of insight proved challenging due to the iterative and collaborative approach undertaken. The learning and recommendation for further studies however, is that researchers may benefit from a more quantitative approach that sets out a consistent recording methodology which would enable this kind of analysis.

Whilst in some ways this was disappointing to my study aim of evidence based it also supported a finding that I also experienced. Throughout the projects I found it challenging with a phenomenological approach, to be capturing thoughts and observations mid-way through practice experiences. Stopping to capture diary entries would inevitably cause a break in the creative process; being analytical and creative use different thinking processes.
This challenge was also considered in terms of having a quantitative set of Diary Entries where ideally, I would capture all experiences regardless of whether they were notable or not. I realised early on that stopping to capture reflections was counterproductive to just being in the experience and would often prevent connected experiences from eventuating or evolving into a deeper experience. Hence an approach of being in the experience was the primary objective and capturing it became secondary. This resulted in the most significant reflections being captured.

When capturing the diary entries, I used language that was colloquial and best described the sensations at the time. It became pertinent to the research that I was only able to talk about the experiences in words that were available to me – there are no defined set of terms for these experiences. There is no formal system for evaluating or describing the sensations of PT. When I used terms such as buzzing or describe energies swirling in my diary entries, it became apparent that there is no way to describe these experiences other than in these terms.

As the study evolved, I observed changes in my research process. I was aware in year four that it became difficult to work with others as they hadn’t been on the same in-depth journey that I had. Notably, I was keen for the collaborators to have experimented with the tuning for some time to establish a deeper understanding of its affects.

In year five I was aware that I was finding it difficult to distinguish the source of my observations. I noticed my compositional approach and artistic expression maturing and wondered to what degree this was due to growing / evolving and how much of that has been prompted by:

a) exploring the frequencies (which have freeing and clarity providing qualities)

b) the process of researching, exploring, analysing

c) personal growth and career development (starting a business).

I became aware as the study evolved that coding the research database into themes was a changing process for me also. It became more difficult to discern whether experiences that I was capturing should be captured as; hearing, tonality, or physicality. I believe this was in part due to my opening as a researcher, surrendering to the phenomenological research approach and observing experiences holistically, capturing them without judgement or categorisation.
Chapter 3 – Summary of Findings

This section provides a summary of the experiential findings throughout the study. Immersion in the PT frequencies over time is one of the most significant findings of this research. Therefore, this section includes a timeline of what experiments were undertaken at what times and how my perceptions and experiences of PT shifted over the research period.

This section also provides research findings from the literature review that support the themes uncovered through the phenomenological investigation of the practice led components of the study. Topics covered include:

- Experiences that have been associated with using frequencies in pure ratios
- An understanding of how frequencies may be inherent to individuals
- What is physically observed when working with natural frequencies
- How the contextual environment may impact or contribute to the phenomenon
- What is the heard experience and how does it differ or contribute to a felt experience?
- How tonality is perceived in relation to the application of pure ratios

This section then provides a summary of the observations captured for the production of each track on the original album, covering:

- The background to the collaboration
- The aspiration or intent for each individual project
- What process was followed to create the track
- Any challenges that were experienced
- Any notable experiences observed throughout the project
- Any summary findings or conclusions regarding the project.

A similar overview of the phenomenology for the re-imagined carols album is also provided including a discourse on how the experiences of this project supplemented and informed the direction of creations for the original album. Two different approaches have been utilised in documenting the creative submissions. The original album treats with each song individually and the carol album is provided in totality providing themes and highlights. These two approaches align to how the two albums were created. The original album consists of isolated projects, whereas the carols album overlapped in the production, often taking learnings from one track and applying it to another. Providing the information in this way provides tow ways of experiencing the phenomenology: one as the lived experience and one as the themes arising.
Timeline of Experiences through Practice and Projects

The timeline of experiences with PT commences in 2006 when I first purchased a digital piano and experimented with the tuning settings. I had previously purchased a set of Pythagorean tuning forks and was keen to explore how the individual frequencies sounded when applied to my original compositions. When first playing the digital piano (a Yamaha with weighted keys) I noticed a tingling between my eyes at the top of my nose which lasted for a few hours after sustained use of PT for 30-60 minutes. Occasional experimentation with PT continued in a practice, performance and workshop setting until 2011 when I formed this PhD research. I recorded the carol God Rest Ye Merry Gentlemen as a first test case of the experience of PT in a studio setting and I was keen to apply research rigour to the experiences I was observing. With the research formally underway in 2012, I looked for opportunities where I could explore the tuning through practice, performance, recordings, collaborations and with audiences.

Early in 2012 I was asked to perform two songs as an opening for a live Tony Stockwell show. The songs requested were well known and I used the opportunity to prepare and perform the songs using PT. I searched online for MIDI files of the two songs: I Believe, and You Raise Me Up and commenced the development of backing tracks for the performance.

I imported the melody and chords from the MIDI files onto the ipad software Music Studio and commenced arranging the songs. Once the initial arrangements were completed I transferred the files into Logic on an iMac computer to access live sampled instruments, PT tuning and mixing capabilities.

During this first performance using backing tracks created in PT I was unaware of the tuning, in my diary note following the performance I wrote “didn’t even think about it” (Jensen 2012 - 2017 DE25)4. Whilst this exercise was primarily about my experience, I was aware of the nature of the feedback from the audience of over 200 people. One person commented that they felt that my voice went through them. And a number of people commented on their emotions, including the welling of tears as taking them by surprise. These comments prompted a further study of the effects of PT in a live performance setting to ascertain in more depth the experience of audience members. Additionally, there were a number of further aspects that I wanted to explore including:

- Using a mixture of Equal Tempered Tuning and PT throughout the performance
- Using a range of live instruments
- Performing in a wide range of styles, and
- Utilising a setting where people could be immersed in the tunings and provide direct feedback throughout the performance.
- From this criterion, a show emerged titled Spring Song. The performance was held at Clover Cottage in Victoria in September 2012 and was held as a dinner and show event.

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4 This reference refers to the PhD database maintained throughout the research; each Diary Entry (DE) has an ID.
Spring Song Live Performance Experimentation

The show was themed around songs relating to Spring which enabled a diverse range of styles to be included in the show such as; jazz, music theatre, folk, art song and originals. It was accompanied by acoustic grand piano in ET, alternating with a digital piano in PT. The show additionally featured guitar and flute. The following table provides a summary of the program, instrumentation and tuning application.

<table>
<thead>
<tr>
<th>Song Number</th>
<th>Title, Origin, Composer</th>
<th>Arrangement</th>
<th>Tuning</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>I Feel So Much Spring</td>
<td>Acoustic Grand Piano</td>
<td>ET</td>
</tr>
<tr>
<td></td>
<td>From A New Brain by William Finn</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Stormy Weather</td>
<td>Acoustic Grand Piano</td>
<td>ET</td>
</tr>
<tr>
<td></td>
<td>Jazz Standard by Arlen/Koehler</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Misty</td>
<td>Digital Piano</td>
<td>PT</td>
</tr>
<tr>
<td></td>
<td>Jazz Standard by Erroll Garner</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Somewhere Over the Rainbow</td>
<td>Digital Piano, Flute</td>
<td>PT</td>
</tr>
<tr>
<td></td>
<td>From the Wizard of Oz by Arlen/Harburg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Later Than Spring</td>
<td>Digital Piano</td>
<td>PT</td>
</tr>
<tr>
<td></td>
<td>From Sail Away by Noel Coward</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>If Ever I Would Leave You</td>
<td>Digital Piano</td>
<td>PT</td>
</tr>
<tr>
<td></td>
<td>From Carousel by Lerner/Lowe</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Autumn Leaves</td>
<td>Digital Piano, Flute</td>
<td>PT</td>
</tr>
<tr>
<td></td>
<td>Jazz Standard by Kosma/Mercer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Spring Is Here</td>
<td>Digital Piano</td>
<td>PT</td>
</tr>
<tr>
<td></td>
<td>From I Married an Angel by Rodgers/Hart</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Spring Can Really Hang You Up the Most</td>
<td>Digital Piano</td>
<td>PT</td>
</tr>
<tr>
<td></td>
<td>Jazz Standard by Landesman/Wolf</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>So Early In The Spring</td>
<td>Classical Guitar</td>
<td>PT</td>
</tr>
<tr>
<td></td>
<td>Traditional Scottish Sea Chantey</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Younger Than Springtime</td>
<td>Acoustic Grand Piano</td>
<td>ET</td>
</tr>
<tr>
<td></td>
<td>From South Pacific by Rodgers/Hammerstein</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>A New Life</td>
<td>Acoustic Grand Piano</td>
<td>ET</td>
</tr>
<tr>
<td></td>
<td>From Jekyll and Hyde by Wildhorn/Bricusse</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Nature Boy</td>
<td>Acoustic Grand Piano, Flute</td>
<td>ET</td>
</tr>
<tr>
<td></td>
<td>Jazz Standard by Eden Ahbez</td>
<td></td>
<td></td>
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<tr>
<td>14</td>
<td>Little Leaf</td>
<td>Classical Guitar</td>
<td>PT</td>
</tr>
<tr>
<td></td>
<td>Contemporary Song by Mirra Jensen</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Being Green</td>
<td>Acoustic Grand Piano</td>
<td>ET</td>
</tr>
<tr>
<td></td>
<td>Art Song by Mirra Jensen</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Fifty-Four Roses</td>
<td>Acoustic Grand Piano</td>
<td>PT</td>
</tr>
<tr>
<td></td>
<td>From A Rose Song Cycle by Mirra Jensen</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Roses Only</td>
<td>Classical Guitar</td>
<td>ET</td>
</tr>
</tbody>
</table>
Whilst preparing for this show, I continued exploring PT in a studio setting by creating rehearsal tracks using the same method as the earlier backing tracks. I also continued to create studio releases with vocals including two further Christmas carols. My observations being immersed in these files included:

“When editing the backing track for Younger than Springtime halfway through I switched from ET to PT, I felt energetic movement in my stomach and around my ears. Like all of a sudden I was hearing in 3D.”

There were a number of experiences documented whilst rehearsing the show. The process started with learning the materials using the digital piano tuned in PT. I found that the PT was generally unnoticeable until playing chords, and was more evident playing independently and slowly. I observed the changes between the two tuning systems when working with backing tracks in the two different systems. After singing song #6 in ET I sang song #21 in PT which brought a sense of expansion. This continued when singing song #9 also in PT, where I felt tingling on the outside of my eyebrows near my temples. I continued with other songs in ET where nothing was observed.

Other experiences included:

• Song #4: Being aware of PT at the end of first two phrases with sustained notes. Felt whole body tinges towards end of song.
• Song #5: halfway through song in PT became aware of expansion around shoulder blades.
• Song #6: When learning the notes in PT I felt an opening of energy at the base of my neck on both sides at the top of my back. This was evident when singing C5 and C6, I observed that this phenomenon was not as obvious when singing with chords.
• Song #9: When learning the notes for this song there were no observations when singing single notes, however when accompanied by chords, I experienced...
buzzing around the top of the head (along a hat line), particularly when singing around C5 and D5.

- Song #9: After singing a number of songs a cappella then song #9 with a PT backing track, I felt my voice fuller and freer, and a sense of being multidimensional. The same feeling continued with song 11, but ceased when singing song #12 in ET.
- Song #21: Found it difficult to sing in tune with PT when learning new melodies from Sondheim composition.
- Song #21: Experienced a light ache between the eyes when singing with PT backing.

Some of the experiences of the Flautist included them commenting that playing with PT for the first time that “you can't really tell the difference”. Although with further investigation and awareness discovering that when playing Autumn Leaves the tuning was hard, needing extra tuning checks. They found that their C# which is usually sharp in Equal Tempered Tuning, was flatter in PT, especially in the low octave. The flautist noted that their teacher usually complains about their C#s, however there are no issues for them getting it in tune with PT.

Despite these observed nuances throughout rehearsals, following the performance the flautist commented that:

“Somewhere Over the Rainbow sat funny, however, was easier to play than normal tuning” and “Autumn leaves sat well, being the best version ever played.” (Jensen 2012 - 2017 DE51)

The 50-member audience was invited to participate in the research through the program notes provided at their tables. The program included a Plain Language Statement introducing the research and inviting their comments via a written survey throughout the performance. The program included the following Background, Instructions and example comments:

**Background**

*Every note in music is set at a 'frequency' measured in Hertz. Sometimes, these different frequencies present a different experience for some listeners, such as being 'more emotional' or feeling that the notes touch them 'more deeply'. Some listeners may simply notice that it sounds different to what they are used to and some may not notice any difference at all. This research project is keen to capture your experiences whatever they may be.*

**Instructions**

- **There are no right or wrong responses**
- **You do not need to have an observation for each song, only when you have a particular experience with a song**
- **You do not need a musical understanding to provide comments, just capture your experience**
• Try to provide insight into 'your experience' (for example: feeling emotional, expanded, analytical, head buzzing, relaxed, energised) rather than what you 'thought' (e.g. it was nice, lovely, enjoyed it)

**Song observation examples:**

• I was aware of the tuning of this song
• The tuning of this song felt 'right' or 'wrong'
• The tuning of this song made me feel...
• I wasn’t aware of the tuning in any of the songs
• The tuning of this song sounded unstable at the start
• This song sounded fuller
• This song made me aware of... (my back, eyebrows, knees, etc)

The audience was a mixture of family, friends and the general public with diverse backgrounds and musical awareness and knowledge. Overwhelmingly, the audience members who participated in the survey demonstrated that they were unaware of which songs were in PT and which were in Equal Tempered Tuning (despite the obviousness of switching between an acoustic and digital piano throughout the performance).

The comments demonstrated that people were largely unable to restrict their dialogue to the experience of tuning and pitch, with the majority of comments providing aesthetic feedback such as: “this song was nice” or “I liked this one the best”. Ball references a study that also had challenges garnering the desired format of responses from participants:

"When music psychologist Alf Gabrielsson solicited the quotes... by asking people to describe 'the strongest, most intense experience of music that you have ever had', few were able to supply any direct link to specific musical events. Rather, they seemed to be more generalized accounts of intoxicating, overwhelming, blissful or elated experiences that happened during a music performance. It is important, indeed essential to recognize that music is capable of producing such intense experiences - but the study shows just how hard it is to figure out why.” (Ball 2010 Pg263)

Comments from the audience that were of interest included; “it reminded me of my childhood” and “relaxing, lovely memories of love” which suggest the flashback phenomenon which features prominently in later projects pursued as part of this research. Comments that seemingly relate to the tuning experience are provided below, however, in cross examination of the comments, the tuning used, and reviewing the recordings, some of the comments relate more to timbre and the song arrangements than the tuning system used.

• Song #4: “Goose bumps, visualised Wizard of Oz. Tuning felt right”
• Song #4: “Lower frequencies generate deep emotions and energise”
• Song #4: “Flute Sounded Off-Key”
• Song #5: “Harmonies feel less natural than in other songs so far”
• Song #5: “High notes resonated more in my ears than other songs”
• Song #6: “Beautiful! Perfect harmony between piano and voice”
• Song #6: “Felt warm and fuzzy! As if it was resonating in me”
• Song #7: “Relaxing when flute was playing and when singing low/deep notes. When you sing higher notes, I feel very buzzy/non-relaxed in head”
• Song #8: “Technically impressive but did nothing for me from a tuning point of view.”
• Song #9: “Different Tuning? Difficult Melody”
• Song #17: “Some of the tuning sounded ‘Off’ - end of verses”
• Song #18: “Not sure what was different with Piano sound, but was nice!”
• Song #18: “Ringing in ears / uncomfortable feeling”
• Song #21: “Tuning felt wrong”

When reviewing the footage of the live performance, it was evident that the songs in PT seemed more settled vocally than those in ET. Whilst the differences in tuning systems were not evident whilst performing, it noticeably impacted the ability to relax into some of the songs. From this study, a number of key areas were identified as recommendations for further research, including:

• exploring the same song being performed in the two tuning systems
• exploring being immersed in PT for a longer period of time
• exploring PT through more diverse arrangements and instrumentation.

Practice and Compositional Enquiry

Following the experiences of the 2012 Spring Song performance, I continued to practice, write and perform in PT. I documented a range of experiences such as noticing that I composed three songs in succession in Gm between May and Sept 2013. Many of these songs formed the basis for the tracks completed as part of the producer project. The following section provides an account of the diary entries throughout this time.

Similar to experiences preparing for Spring Song, I continued to experience buzzing in various locations in my physicality. On one occasion, I was listening to music by Jonathan Goldman, whose website is called Healing Sounds and the track was centred around frequencies at 528 hertz. I noted buzzing in my groin which then moved up my body towards an expansion feeling at the bridge of my nose, moving up between the eyebrows with a powerful sensation. This experience was significant to this research as it mirrored what I was experiencing practicing in PT where I would document: “buzzing at bridge of nose an hr after a long session singing in PT” or “buzzing on nose and redness around area. i.e. blood seemed to go there after two hours playing piano in PT”.

Another consideration through this period of practice in PT was the idea of musical familiarity. I was aware that when I listened to the three carols I had released in PT that the tuning seemed not as obvious. I believe it is the conditioning that I experienced being immersed in these tracks for long periods of time during the production of the tracks.
On another occasion, I found whilst rehearsing in PT that the tuning was very obvious, I found it annoying, and was almost tempted to change the piano settings back to ET. As I was at the final rehearsal stages of polishing the performance I wondered whether I was looking for greater accuracy and perfectionism which is ingrained into any professionally trained musician. In this regard, the idea of familiarity is linked to learnt behaviour in performance practice.

**Instrumentation Experimentation**

During these early experiments, I also explored different instruments and the effect of PT in different timbres. Notably, when Playing Bach Allegro No3 in PT on the digital piano I switched the grand piano setting to a harpsichord, I noticed a “ping at the back of my head”, which was two inches to the right of my ponytail.

I also experimented further with live instruments such as the acoustic guitar where I felt the resonance of playing the piano and guitar together was amplified approximately five times more than playing a piano PT note by itself.

I also explored the PT experience on the violin, tuning the open strings to the PT piano. I observed when tuning the G string that there was a resonance on the left side of my stomach that was awakened when the violin string clicked into what felt like the right frequency. I also found I needed to further adjust some strings slightly so that they sat better on the instrument. I found that my playing was freer and I was more aware of intonation than previously. I also observed that it was easier to play as I wasn't aiming for the right tuning that I was taught as a child, rather, I was able to find the tuning that felt right. This became freeing for both my finger placement, hand adjustment across positions, tone and vibrato. All of these aspects were liberated by thinking in pure intervals.

In December 2013, I purchased an acoustic 1970 Yamaha upright piano for the purpose of experimenting with tuning, playing and recording. I tested 20-30 comparative instruments looking for the greatest resonance that was consistent across the full range of the piano. In the first few months I left the piano tuned in ET as a comparison to the digital keyboard in PT. I did find it hard to sing in tune with the ET piano after singing with PT where I had become accustomed to more fluidity in my vocal tuning. In the first few days adjusting to the ET frequencies, I noted that I had cloudy ears where the resonance felt muffled and also experienced some vocal strain.

Playing and singing one of my original songs on the ET piano for the first time after working with PT I noted:

“Thin sounding, horrible to sing, I feel tightness and sharp pain on right hand side of my chest. It spreads throughout chorus and second verse, the sensation lingers after I finish playing, which I haven’t enjoyed at all.” *(Jensen 2012 - 2017 DE166)*

In contrast, once I had tuned the piano to PT I documented my experience as follows:
"The first song sat awkward, as I was exploring I felt the frequencies become more resonant and my vocals were starting to adjust. By the second song, Divine, it felt as though everything clicked into place, the sound was more resonant, my vocals felt and sounded connected, there was an earthiness about the sound which sat lower, and at the same time soared; my tone became more guttural and resonant and comfortable and... awesome!" (Jensen 2012 - 2017 DE170)

Practical Tuning Experimentation

Following the early experiences with the new piano in ET I ordered a piano tuning kit and downloaded a range of apps that provide tuners with alternate tuning settings. I spent approximately six months experimenting with tuning the piano myself. My tuning experimentation focussed on:

- ensuring pure intonation in the central octaves
- tuning the full range of frequencies for varying experiences at the extreme octaves
- variance between my inherent resonance and that of the tuning application software
- ongoing adjustments through practice period to enhance the PT experience.

I found the exercise to be valuable to this study as it increased my awareness of:

- the challenges in achieving perfectly accurate tuning of piano strings
- the nuances and feelings associated with perfectly tuned intervals
- the highest and lowest notes being far harder to achieve tuning accuracy
- the quality of various tuning software available
- sensitivity of some notes over others (i.e. C#5 decay of 10 Hz after note struck)

Following these experiments, I was fortunate to meet a professional piano tuner from Poland with an interest in PT in September 2014. We set up a session to tune the piano and I documented the experience in detail. He brought a range of reference materials and I used the tuning software in the background to assess where there was alignment between the human and technology approaches. It was fascinating to watch as he was challenged by wanting to achieve perfect intervals within the closed octaves of the piano.

He was reluctant to continue the process after completing the first octave as he seemed stuck at the comma and the inability to continue with the perfect fifths. He asked, “which PT?” I wanted to go with as though experimenting with the pure system (like so many others had) would improve on this sticking point. He referred to the reference materials and eventually suggested the option of stretching the octaves. I was keen on this approach as it aligned with reference materials I had reviewed that suggested the benefits of the unending spiral achieved by not closing the octave. Furthermore, I had read from Beament that “many people like slightly sharp octaves” due to their brightness. Beament also outlined how musicians had commented that his Roland
electronic keyboard in ET had flat high notes. He questioned whether this was a learned tuning rather than an inherent one (Beament 2003 Pg73).

As the piano tuning continued, we became stuck at the second octave similar to the first, my diary entry captures the seemingly all-consuming frustration experienced by this highly regarded specialist in his field:

“The flow of pure 5ths goes silent and his body language shuts down. He crosses his arms and leans back from the instrument and rubs his chin in frustration. He puts one finger across his lips as though shushing a child as if somehow this will make the wolf interval go away. He looks to Jorgensen’s tuning compendium for more answers as though it will tell him how to make the wolf interval go away. He calls the tuning system 'primitive' under his breath but acknowledges that Pythagoras was a very intelligent man 'mathematical'.”

After this hurdle, we continued in acceptance and completed the full piano tuning in PT. As he was tuning the intervals, stretching them from pure and just above and below I felt them shifting and settling in different parts of my body. I documented a range of sensations, including:

- “Low heavy wolf interval felt very much in my heart, then felt a higher stretched interval in my lower back.”
- “Definite movement around cheek bones and temples on some intervals”
- “G4-D4 interval played in succession, the repetition of the pure interval had a calming effect over me. After playing the octave and the fourth, returned to the G4-D4 fifth and again I felt the interval settle in my heart.”
- “Bb4 to Eb4 sense of surround sound around my head.”

I became aware after a period of time observing energies shifting in my body and noticing where the different frequencies were resonating that this was an exhausting activity. I switched off my physical awareness and listen rather than experience. I found that being moved around so much in the tuning process had been somewhat overwhelming and scattering to my sensibilities.

Following the session, we were both pleased with what had been achieved and the earlier frustrations seemed to be resolved by a successfully completed task. We discussed the keys that I’d been writing in, we played Gm in the newly, perfectly Pythagorean tuned piano and observed it had a dark characteristic which was full and resonant. I also mentioned I’d been writing in D and he advised that this was the best key. We discussed how the B to F# interval would always be the wolf interval the way my piano had been tuned and as a parting joke(?) suggested I not use the black keys too much!

**Impact of PT on Performance Practice**

Performance practice on the newly tuned PT piano throughout 2014/15 delivered a range of experiences, however, noticeably many of the early diary entries refer to the ease of playing. The many descriptive accounts of this sensation include:
• “immediately my fingers feel more relaxed and connected with the instrument there is balance and ease and the energy seems to flow between me and the instrument freely”
• “fingers seem to be melting, so relaxed and at ease, tension flowing freely so that keys and fingers feel as one”
• “keys felt more pliable, buoyant, softer, more at ease, everything flowed with such enjoyment”
• “feel more connected to the piano, hands touched the keys closer and more freely like an embrace, they feel like an extension of me”
• “fingers loose and so easy to play”

Throughout this period, I continued to document accounts of other awareness of PT affecting my physicality, including; a radiating heat on the ball of my left foot when a sequence resolved, as if something was leaving my body, draining through that point. Sensations across my temples, chest and back were also documented, however these physical sensations seemed lessened at this time of performance practice as though my body had adjusted to their effect. By the end of 2015, I documented how PT had completely normalised for me, noticeably that there was no longer a period of adjustment between how I am feeling and my connection to the frequencies.

I also found that similar to the ease of playing there was also an ease of singing where my voice was noticeably more relaxed and open with a “richer resonance that seemed to blend with the vibrations on the piano strings”. I was also frequently performing live with acoustic originals at this time. I had a significant experience at a gig where I performed in ET but had been practicing in PT. The venue owner commented on the performance being the best singing of the residency. Even though the Steinway grand was tuned in ET I felt as though my voice was freer as though the effect of singing in PT in rehearsals had carried over into the performance. He commented on how connected the performance was with a richness and clarity which I had felt too.

As my performance practice in PT was advancing through these experiences, I contemplated how the differing characteristics of PT frequencies affect the way you treat each note in performance. For example, you might play a 3rd a bit softer so as not to accentuate a wolf interval. I observed this occurring naturally, it wasn’t a technical or intentional shift. Rather, it became part of maximising the qualities of each of the notes and how they come together harmonically.

I also observed that my improvised piano playing mindset shifted from notes you can play to notes you can’t. Meaning, If I was improvising a song, originally, I would consider what key I was playing in and mentally decide what notes comfortably work within the improvisation. Working with PT I found that I would consider what key I was in and only consider what notes wouldn’t work. This mindset shift resulted in the inclusion of a far wider range of notes and chords in my improvisations than I had previously included. I felt that this was the result of the rich harmonic spectrum that the Pythagorean resonances create. That playing more diverse harmonic combinations added to the vibrancy of the music. I found that the occasional note that wasn’t primarily in the harmonic structure added to and blended with the harmonic palette in a way that was less distinguishable than playing in ET.
An extension of this concept was observed throughout the producer project as I became aware that my compositions were moving more towards soundscapes. I considered this as a result of the idea that the words, melodies and phrasing have less significance on the experience of the music than the pure frequencies themselves. I found this confronting as an artist, as though all my previous efforts trying to perfect compositions had somehow been wasted. I also observed a greater focus on the rhythmic elements of the tracks where I moved away from using block chords in the arrangements.

Creative Submission Dialogue

The following section provides a dialogue on each of the tracks forming the creative submission for the producer project. As this activity was completed over a three-year period, I was able to observe the evolution of technology available and the development of my own composition and production skills. Notably, in mid 2015 when upgrading to Logic Pro X, I found it difficult to find the alternative tuning settings. In the software update they had been moved to advanced options, and are now called historical tuning.

Throughout the production period I felt that singing on the recordings was the most challenging part. I found it difficult to be in the right headspace for the intended performances. I was aware that the analysis of PT experiences increased my critical appraisal which made it more difficult to be in the moment for the vocal performances.

In the final stages of editing the tracks in the producer project, I heavily used the new functionality of flex pitch in Logic Pro X whereby I set all vox lines to perfect pitch using the set all notes to perfect option. I felt that in some ways I have developed an addiction to the frequencies, and that perfecting them in the recordings provided clarity of the frequencies and enhanced the experience of PT.

Fall in Love

This collaboration commenced in January 2015. The producer (producer #5) and I were introduced by a colleague whom recognised our similar interests and, being aware of the research study, suggested participation in the project. A short introductory conversation confirmed their interest to experiment with alternate tunings. They also demonstrated a high degree of technical knowledge on DAW capabilities and importing scale files to enable the use of alternate tunings in some software programs.

The project commenced with independent work by the producer creating an instrumental track in a commercial pop vain. In the producer’s words, this process entailed (email:190215):

"I've listened to your voice and songs and I'm hoping this key and tone of the backing track will suit you."

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5 Vocals in contemporary music are often referred to as Vox.
The initial conversation on the style of the track was the most mainstream of my career. Producer #5 informed that whilst his musical interests and experiences were diverse he had been recently enjoying the creation of mainstream commercial dance music. Whilst my artistic preferences err on the side of alternative and/or crossover, I was excited by the opportunity to apply the Pythagorean frequencies in a truly commercial track.

The intent of this collaboration didn't seek to enhance the experience of the track through the application of the frequencies. Rather, the approach was to treat this track as though it was in ET and to just observe if the PT tuning was noticeable. Additionally, we considered whether PT enhances or detracts from a mainstream commercial release recording. An excerpt from my email correspondence at the rough mix stage further demonstrates the aspiration and intent of this collaboration:

"I think for the sake of the genre, and the premise of the collaboration project to just create things as you usually would (but in PT) feel free to make the vox as commercial as possible! I often find producers hold back with my vox being tempted to leave them quite natural, but I'm particularly keen on this track to sound as mainstream as everyone else." (email: 260215)

Of all the collaborations, this was the quickest to complete and perhaps this is due to the uncomplicated approach. We weren't seeking in this collaboration to explore the PT experience, rather our intent was to create a commercial track and to observe, if in this process, there was a PT experience. At the first email correspondence after commencing the project the producer had completed 70% of a backing track suitable to create a lyric and melody and record vocals prior to them being mixed into the track.

The collaboration was working interstate and largely over phone, email and Dropbox file sharing. Accompanying the first version of the track were suggested time codes for the structure of the song and lyric placement. There were suggestions for the inclusions of hooks, soft hooks, harmonies and creative suggestion for the bridge such as a reverse hook inclusion. I noted at the time that this approach is synonymous with the creation of a commercial track, the following of a formula that achieves a known response i.e. it is a format that produces a popular song that takes people on a journey. Producer #5 articulated this as (email:190215):

"If you do stick to the format I've laid out, you'll end up with a very radio friendly 'club banger' ".

Whilst the structure was laid out clearly the collaboration was also flexible and supportive, I was encouraged to feel it and to request edits if/where there were aspects of the track that weren't working creatively for my part in the process. From receipt of the backing, I was able to provide the guide vox within five days and the lead, double, and backings and harmonies provided within a further four days. This was a very short and simple process. Rough mixes were completed in March 2015 and a final mix in early May. In the process of finalising the track and discussing commercial release

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6 Cloud based storage application
options we discussed the challenges of this track being in alternate tuning potentially limiting its use by DJ’s who blend tracks together.

The only challenges experienced in this collaboration were at the initial commencement stage and discovering software tuning options. In our first correspondence, the producer commented (email:030115):

"I had a go a re-tuning one of my Logic Pro X sessions to PT and I had no luck - it seems to not change the tuning for a pre-made session or maybe it doesn't re-tune third party synthesisers but only the first party included instruments."

This prompted a discussion on studio engineering know-how with suggestions on how to get around PT DAW challenges. They included utilising OMF files to provide the bounced down audio and to run through Logic and pull an auto tune filter over the top. We also discussed Melodeon as a plugin option that could possibly work as it alters the formants. This producer preferred DAW is Massive (which doesn't import scale files). I contemplated how producers in mainstream genres were using applications that are being built fit for purpose for the modern genres and not providing the adaptability for alternative tunings.

Within our correspondence, this producer advised that a friend was present in his studio whilst he was working on the track (email:200215):

"He is a great pianist and has perfect pitch and he said he noticed the tuning straight away. I asked him if he liked the tuning and he said no but also stated that could be because of his training."

The producers’ reflections on the collaboration shifted over time: "I like the track even more than I did before now I've heard it mixed." Despite a fairly straight forward creative and mixing process, this track, like others, raised the most queries regarding the auto tune process of the vocal lines. Producer #5 questioned the best approach (email:060315):

"Do you know if Logic's Flex Pitch correction works with alternate tuning? I started using it and it produced some blips and errors (usually I use AutoTune or Melodyne) but I would like something there to get a little bit more commercial with that vocal sound that works with the tuning scale."

This collaboration was an enjoyable process and achieved the original intent of a commercial release dance track. Whilst there were questions regarding tuning software at both the initial and final mixing stages, the use of PT was largely unnoticeable for the majority of this collaboration. The producer commented on the final mix that the track was: “not balancing the mid frequencies as well as usual” and that the “buzz synths in the chorus” were questionable "I made them from scratch so maybe too many harmonics in them for PT?”. Despite these reflections, both collaborators noted enjoying listening to the track throughout the process. And other listeners commented that they couldn't discern that it was in an alternate tuning. When presenting the track to

7 A DJ is a disk jockey which is someone who plays music at live venues or on the radio.
8 OMF files are Open Media Framework Files across video and Audio platforms.
an industry A+R representative, they commented: "Wow, Fall in Love is a strong track".

Unstable

This collaboration started when I was introduced to producer #4’s music on Facebook by a mutual friend in September 2014. I noted that he was looking to collaborate with singers and was interested in experimental production. When I contacted him regarding the study I was met by an enthusiastic response that included fascinating and fun to describe his observations of the research project. The producer undertook to do further research "into tuning my software synths and DAW to PT" and after signing ethics paperwork the project was underway.

In our initial correspondence, we discussed artistic preferences in collaborating, both contributors were flexible in the approach. As the project progressed the collaboration occurred organically with the producer providing a track containing the backing as an initial idea - this track resulted as the final mix released. As I started the lyric process for this track, I was committed to the genre and style of the track and ensured that the lyric was simple, catchy and repetitive. I was inspired by a conversation with another composer the day prior; we were reflecting that playing the PT piano was much more of an unstable experience than ET keyboards. This concept prompted the idea of how this could be reflected in the lyric of a commercial dance track and the idea of an unstable relationship evolved.

Whilst the initial guide vox was prepared in November, producer #4 was unavailable throughout November and December. Both collaborators were happy with the direction of the piece at this stage. We reconnected the following year in February, April and July, when the producer, after a period of absence from music was keen to start from scratch to explore a slower option. Whilst a few new ideas were forming, I was still keen to progress with the track that we had. This was especially so, as I wanted to explore a new approach to the vocals that was lower and more spoken in the nature of the vocal tone. Unfortunately, the producer was unable to further participate in the study and with their permission, the final vocal mixes were independently mixed to the initial backing.

The inception stage of the collaboration, when aligning DAWs and ways of working in each of the projects, has been a defining moment for whether the project continued or not. The initial response from this producer summarises the challenges and way of thinking about how to undertake the project technically. This includes consideration of work-a-rounds, and limiting the use of tools available if there was a more complex (and often unpredictable) solution (email:131014):

"I use Ableton Live 9 and various vst synths, mainly the Native Instruments Komplete Suite. Ableton doesn't have this option, but it can be done using a max for live download apparently. But I've been reading and it sounds like its easier to tune the individual synths rather than the DAW (Ableton) because each synth

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9 An A+R representative is an industry title for an Artist and Repertoire Agent
10 An online social networking site
is tuned separately. Tuning Ableton itself would only change the built in synths, which I don't use much. FM8 is the only one of my VST synths that I've found so far to have microtuning and PT as a preset. But I've only looked at a 3rd of my synths. From what I've read majority of my synths can be changed by using a tuning file if needed, its just not as easily done. FM8 is quite powerful and I'm happy to get started with just this synth for now and look at tuning my other synths if I need."

The experiences of PT in this collaboration were largely related to the understanding of the tuning conceptually and the technical application of it to the project. One of the initial questions from producer #4 is representative of what most producers in a similar situation would have found after a google search on the topic (email:091014):

"Is it just detuning my synths so that A is 432hz and not 440hz? Or is it something completely different? Googling too much confused me."

Regarding the recording and mixing of the vox tracks, I was largely unaware of the tuning. I was more mindful of vocal style throughout the project. I was aware that the initial guide was not sitting in the track the way I felt it should and significantly revised the vocal line on the lead vocal takes. When mixing the vocal lines and adding effects I was aware of matching the style of the track. The use of delay was assisting to embed the vocal line in the depth of the frequencies of the backing rather than for the vocal line to sit on top of the backing. The bridge also was a place where particular attention was made to create a sense of depth in the track. Layers of harmonies, particularly fine tuning on volume, panning and selective fx were all techniques used to enhance the PT experience.

Whilst this collaboration was a long process resulting in the initial contact to final mix occurring over 18 months, it has consistently remained a strong song on the album track list. This is due to its simplicity in thematic idea, the final vocals sitting easily within the genre and the uncomplicated nature of the melodic content. This collaboration raised very few reflections on the experience of the tuning and had minimal issues with the auto-tune stages with the vocals.

The use of synth sounds that sat well together independently resulted in a foundation for the vocal line to also sit well with regards to the tuning. This track has been well received with industry representatives also, particularly with regards to the vocal style (email: 030616): “I love your voice the most on this track it’s not so singer perfect”.

However, others have suggested that it does not stand out in terms of commerciality (hooks, variance, uniqueness) as some of the other collaborations have.

A New Day

Producer #2 shared an interest in non-standard tuning and a spiritual exploration of the benefits of music. We met in July 2014 after I had purchased a new AKG studio mic from Factory Sound11. The mic wasn’t working the way I thought it should so the store

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11 Music industry equipment supplier
sent a studio engineer who lived near my studio to test it. We discussed the research project at length and his interest in participating. In email correspondence following, producer #2 stated (email: 170714):

"After chatting to you last night you inspired me to get back to the search for application of geometric shapes in music composition."

In subsequent emails, he demonstrated his interest in software applications that supported or enhanced the ability to work with non-standard tuning such as Mach Five, which easily enables the import of scale files. Working with producer #2, highlighted the varying degrees of knowledge across the collaborators, both from a technological point of view and also the theoretical and research interest.

Prior to commencing the collaboration, in October 2014, producer #2 offered to work on the mixes for four of the Pythagorean carols that were due for release that December (insights from these sessions are provided in the overview of the experiences producing Pythagorean Christmas carols). The collaboration on the original track commenced in March 2015.

We discussed working from an existing song or collaborating on a new piece. The main aspects that we considered were various musical styles and timbral effects that may be enhanced by PT or at least, would be interesting to explore. Producer #2 had an extensive sound bank and we listened to various samples to influence our thinking. Two of the prominent styles that were discussed were world fusion and retro with a funky modern twist.

Whilst we ultimately decided to work with a pre-existing composition, many of these original elements that were discussed for the track can be heard in the produced version of the song, which differs significantly from the original acoustic version. I provided the MIDI file for the acoustic piano/vocal of the track and a live sound recording of the song to get the project started. As we had already discussed the range of influences that could be included in the production, I left the track with the producer to create an instrumental version to record the lead vocals to.

On first listening to producer #2’s instrumental track, I immediately aligned to the new feel he had created. I felt it had tribal and aboriginal elements that suited the lyric ideas of going on a quest, life energy and exploring unfamiliar lands. At the request of the producer we experimented with recording live PT piano to add a richness to the sound recording. We discussed and explored breaking up the rhythmic elements of the original piano part and how the stability of the beat might be linked to enhancing the tuning experience. In the recording process, we discussed mic placement in the piano to capture the PT frequencies, however, it was decided that this was unlikely to make a difference.

We encountered a practical challenge when deciding to include the live PT piano, as the original sound file was set at A=440 and at this point, had already recorded the lead vocals. We realised that the PT piano was tuned at A=432; with the rest of the production in audio at 440, the best option was to run an auto tune filter on the piano to bring it back up to 440. It was, however, a difficult process to record the piano line.
against a track that it was clearly at odds with harmonically, particularly as I was listening to a vocal that I found to be gratingly sharp. I also found that playing the high-pitched runs on the PT piano against the track were grating against my nerves.

By the 5th take of the piano we both observed that it was sitting in the groove better as I had become somewhat normalised to the dissonance. We discussed how it seemed that having adjusted to the frequencies, I wasn’t fighting the piano with my playing, which meant that I could then focus on playing into the groove of the track. This ultimately resulted in a scenario where playing into the groove meant that the frequencies were naturally more aligned. When editing the live piano with an auto tune filter to bring it back into alignment with the track, we observed that the plugin software tuners were struggling with the lower frequencies and the accuracy in analysing and adjusting the pitches. Producer #2 moved the tuner into metering in the channel which made a significant difference.

Throughout this process I was aware that Producer #2 was keener to persist with including the real instruments than I was. Throughout the recording and mixing process of the live PT piano I very much wanted to move back to the previous version where there was more precision achieved through the software instruments. However, when listening to the two options, one with real piano and the original without, I automatically observed that the live piano provided a richer quality that was “penetrating through my head.” (Jensen 2012 - 2017 DE293)

To resolve the remaining dissonance challenges, we experimented with setting the root key of the tuning settings to D and observed that this “made a HUGE difference” (Jensen 2012 - 2017 DE260), the MIDI and the live piano were sitting much better together. This adjustment, whilst seemingly obvious had not been required in other tracks that were produced with synthesisers alone. We found, however, that the synth bass was sitting much better and the vox line not as sharp. As we worked to resolve the issues, and after sitting with the dissonance for some time, I was aware of a pleasing sensation of “connectedness and relaxation around the back of my neck” (Jensen 2012 - 2017 DE260). However, as we progressed further into the track and became aware of a bass note in the live piano line continuing to cause conflict, I was aware of a “sharp stabbing pain in the right side of my chest bone” (Jensen 2012 - 2017 DE260).

These pronounced physical experiences to this process are of interest as producer #2 had reflected on the strong prominence of the repetitive nature of the D and the strong use of I, IV, V in the song. It was this reflection that prompted us to explore adjusting the root key setting. He reflected in his words how the simple harmonic structure was:

“Creating a sense of peace and stability with the harmonies setting a soothing, stable atmosphere that doesn’t grate on you.” (Jensen 2012 - 2017 DE255)

I asked producer #2 to reflect on his mental focus through the mixing process. He replied that he was “lost in the sound and the simplicity of the experience” however couldn't say “whether this affect is more or less than a usual mixing experience.” (Jensen 2012 - 2017 DE255)
The challenges that we encountered in recording the live piano were an interesting experience as I found the sensations carried over to the following day. When listening to the PT carols that had been released, I was observing the same annoyed sensation as I had with the frequencies grating on my nerves, particularly listening to the tracks with vocals. I noted in my diary entry at the time that I “felt like the tuning was trying to take me somewhere I wasn’t prepared to go.” (Jensen 2012 - 2017 DE256)

Concluding this collaboration, producer #2 shared the idea that vibrating at a higher energy and creating from that place doesn’t always connect with people that are vibrating from a denser space (i.e. a less connected or more mundane existence) but when you do achieve a creation from a higher (more connected) space that when it does connect with people that it is a far more profound experience.

**A Love that You Own**

*A Love that You Own* was a song co-written in 2007, however, had never been recoded. Due to the harmonic structure of the track, I was keen to explore the application of PT and therefore self-produced the song. The composition uses a change from C minor to C major at the start of the chorus (TC\(^{12}\) 0:39) to affect a moment of realisation and continues to utilise this harmonic effect to add dramatisation within the chorus.

As the harmonic and melodic characteristics of this song are more pronounced than some of the more mainstream collaborations, I was keen to explore whether the compositional elements that create lyric dramatisation are enhanced or detracted from with the use of PT. The lyric was inspired by a male member of my performance band who had been verbally and physically abused by his partner. Whilst the lyrics are not directly onomatopoeic, the original vocal line contains a number of large intervals that reflect the instability of the thinking process associated with this social paradigm. When recounting his experiences, the band member was literally jumping around in his thought process, and this is reflected in the jumping intervals in the vocal line.

Interestingly, in the final mixing process I found the instability of the vocal line to be too great and re-recorded the lead vocal with a number of these large intervals reduced to a minor second, rather than a minor sixth. The original vocal line with the larger intervals forms the backing vocal in the final mix. This backing vocal still creates the original sense intended in the composition and the more stable new lead vocal assists to provide a more grounded storytelling approach.

The re-take of the lead vocal was done in one take with no pitch edits needed. I considered how this was a result of listening to the track repetitively through the mixing process. When I moved the bridge lead vox to the fx track I set all notes to perfect using the flex pitch functionality. I noticed that whilst the notes were in tune in PT and didn’t need to be adjusted for them to sound in tune, setting them all to perfect just enhanced the experience. I tried to resist setting the lead to *all perfect* but caved! The call of a perfect PT sound had become too great.

The instrumentation on this track commenced with the piano MIDI line set to PT at A=432.1hz. A simple but resonant bass line was added and a range of drum options

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\(^{12}\) TC short for Timecode indicating where in the audio file the text is referring to
were experimented with prior to the resulting sparse rhythmic line. The rhythmic section is contrasted by a bell effect panned far right to create a niggling, nagging sensation in the back of your head (when listening through headphones) again, to reflect the storyline being narrated.

The production of this track had a number of challenges with regards to the tuning. Whilst a live piano line was recorded as part of the process, I captured in my production notes; canned live piano, couldn’t get it to sit well. On further exploration and analysis after the fact, I could deduce that this was because the live piano line was essentially a top end melodic idea that was so contrasting to the stability of the MIDI chord accompaniment, that the later was making the former seem more out of tune, than it otherwise was.

The tuning of the vocals also proved challenging in this track. The initial guide vox felt very out which prompted me to explore the various tuning settings available. Rather than using the usual pre-set option for PT, in this instance I experimented with the user scale which I referred to in production notes as disastrous. Upon returning to fixed 12-tone PT, I continued to explore tuning within the track and noticed that when I applied an auto tune plugin on the software instrument piano, the filter was suggesting that the software was not 100% PT. I reflected upon other variants that could be responsible for this, including the use of the humanise function which slightly varies the time and pitch of notes to make them more lifelike.

The MIDI piano line in this track contains a number of repeated notes, for example, throughout the verse (TC 0:20), there are 20 C3 crotchets played in sequence (this effect represents the repetitive nature of abusive). What is interesting here is the sensation that (particularly when the track is soloed) each instance of this repetition sounds as though the pitch is bending significantly through the note. This experience differs to when the file is set to ET as the global tuning, where there is no difference within each note to the next note. The additional observation is that this effect lessens over time, due to the repetitive nature of the line becoming normalised. In the fine editing process, I noted that at bar 41 (TC 1:20) the bass line chord is C, but C# in octave one seemed more in tune so I used this adjustment instead.

Despite some of the experiences producing and recording this track not being as straightforward as others, I found that this challenged me to a better outcome. I explored more through the creation and production elements of this track, and find that I am pleased with the final result. The track had space around the frequencies which has enabled them to bend and rest. I found in my final production notes that:

“I felt the mix sitting so well that I had to check that the auto tune was off and that the project setting was still in PT.” (Jensen 2012 - 2017 DE292)

Taken by the Beat

I found producer #1 when invited to join the Pythagorean Intonation Group on Facebook. I contacted him regarding participating in the study and the collaboration commenced in June 2014. In our first correspondence, this producer referred to his skills as amateur however shared a passion for experimenting and understanding the PT
options and the experience of non-standard tuning pitches. In the early stages of this collaboration this producer was using a ready-made template to assist in the construction of the track. As the template provided a foundation, it resulted in a number of limitations and issues being identified such as changing the BPM\textsuperscript{13}. Once the lyric and chords had been provided, this enabled the producer to start again building the track based on the vocal guides.

Regarding the intent of the collaboration, the focus was primarily on the experience of the tuning and a style was decided upon that was aligned to the producer’s current interests (email:110714):

"I'm aiming for something epic, like what we might hear in a modern trance dance music, but that would be the vocals, my music part could go off the path into deeper, darker, bass music."

After hearing some of the initial ideas, I was largely prompted by the colours in the track and wrote the following regarding my lyrical intent (email:130714):

"Thematically, I was thinking along the lines of being ‘Pulled’ i.e. we live in these high tech environments and are constantly pulled from one thing to another so was thinking the verses could be about all this stuff going on around us constantly and the chorus just about switching off and being present in the moment."

When experimenting with the BPM of the track, the producer was inspired to drastically adjust the tempo to experience the tuning in new ways (email:230714):

"It really takes it down a level. Really breaks it down.... Have you ever thought of spoken word or rap?"

Whilst the final track didn’t result in spoken vocals it is interesting to note that this was the first collaboration and four of the tracks that followed resulted in vocals that were sparse and/or spoken.

Both collaborators used the Logic Pro X DAW which enabled a deeper collaboration than others as we were both working in the same file. There were some challenges with compressing and sharing files, however overall it was a benefit to be able to view the creation of the track as it was evolving, rather than just using my ears to provide feedback.

To commence the vocal writing and recording process, I listened to references tracks in the trance genre as I was less familiar with this vocal style. I was aware of how much trance vocal lines seem to blend into the track which prompted a consideration of the benefits of working with PT in this way. In response, I intentionally blended with the track and found myself more aware of the beat than usual. The rhythmic elements felt more penetrating and I was inspired to write a rhythmic chorus using the words taken by

\textsuperscript{13} Beats Per Minute
the beat. Further questions around how PT enhances the experience of rhythm were prompted by this initial collaboration.

This track prompted diverse experiences for both collaborators. When listening to just the intro of the first take of the MIDI in PT I captured:

"The sound immediately feels as though it has the rich resonance that I have become accustomed to with PT and it draws me in, I feel inspired to sing with the track and feel as though the notes are penetrating spaces behind my head in perhaps a 30cm diameter almost reminding me of the bands around planets such as Saturn." (Jensen 2012 - 2017 DE185)

In contrast, when listening to the rough mix of just the backing in PT, I captured:

"Love the sound and the feeling of it being quite penetrating, however after a few run throughs is feeling a bit metallic and intrusive in my left ear. After a few minutes have passed I feel energy shifting around my left adrenal at the front. A type of knotting, spasm, twitching and re-settling." (Jensen 2012 - 2017 DE186)

Additionally, I captured that when listening to a slower version of this track for the first time:

"also found it to be relaxing, but found that the songs coming up in my playlist afterwards to be quite stark and ‘intrusive’. Almost felt as though after a few listens of taken that it was stabilising and had somehow become a bit ‘addictive’." (Jensen 2012 - 2017 DE189)

Producer #1 similarly had experiences that seemed to be bigger than self. He remarked that:

"I was saying the music is really helping me relax.... Kind of slowing down time" (email:230714)

Producer #1 provided a final diary entry which captures what he believes the benefits of the experience to have been:

"As I sit here listening to Taken by the beat, a song tuned to (432hz) PT, I feel closer to perfection. But what is perfection, without feelings? PT is not dissonant like ET. There are two beneficial effects upon me after listening and working on this PT song for the last nine months. First the auditory pleasure. The notes play off each other and don’t clash. They harmonize. The second benefit I have experienced is emotional. It’s like in my heart centre a warm glow spreads upward. I feel like I have found a key to open a door and the light is rising. I’m wondering if the (432hz) PT is loosening the constrictive controls around my heart area. This is the first physical effect that has happened to me since I started with the tuning. It starts on its own, and it’s warm but a little scared, so I behave as a witness, and I’m trying to encourage it, and ultimately, let it go, because I see a peace behind the curtain. I almost believe that I can begin to walking meditate. To flow through my life in a state of bliss while I let go of my
feelings and open the well of happiness. I feel mostly compassion, and I’m growing closer in my relationships. My challenge to myself is to remember this heart centred power and use it when I’m confronted by fear from other people. in the past my greatest enemy has been getting disturbed by people who are freaking out. I think If I can reach a zen point I will no longer be dragged down by negatively spiralling people. Maybe I can spread a little calmness to them instead?” (Jensen 2012 - 2017 DE258)

Beyond Belief

This track was one of the last to be included in the project, and was commenced late in 2015. The track was self-produced and started as an experiment in sound and production with the addition of some lyrics to echo the sentiment of the music. The experimentation was the culmination of four years of exploration producing in PT and I was keen to create a track without a song already composed to further test a pure experience of working with the tuning.

The production elements are simple and sparse with a focus on the space between. I was conscious of melding together a variety of different textural elements such as the strings, brass, human bass and strong but simple rhythmic components. The vocals, and lyrics in particular are an extension of the melodic accompaniment rather than being a stand-alone vocal with backing.

The thematic idea of looking down marries together with the out of space textural elements. The lyrics that follow (TC 0:34), echo the sentiments of the phenomenological enquiry I was embarking on with this track; looking left, looking right but most importantly looking through. This lyric reflects the ability to step away from preconceived notions of how music, in particular temperament, should be experienced. The subsequent lyrics explore the seeing that occurs after deep looking. Upon seeing (TC 0:45), there is, as with phenomenological enquiry, a process of watching (TC 1:14), of further investigation by the process of repetition which occurs in different conditions. It is only after the looking, seeing and watching, that the touching occurs (TC 1:30); the process of connectedness. I have experienced through working with these frequencies that they can facilitate connectedness with self and others, but it is only through deep exploration that this has truly occurred.

The process for creating this track focussed on timbral exploration. In the first instance, it was a process of selecting loops, sounds and rhythms that would create space - that would allow for Pythagorean Frequencies to be appreciated. Whilst there are many layers in this track, they operate in a way that allows harmonic resonance of the frequencies. They resonate freely and settle within the space without being drawn towards another harmonic resolution.

When recording the vocal lines, the initial melody is a very pure and simplistic selection of the tonic, perfect fifth and perfect fourth (I,V,I,V,IV). Whilst this was not an intellectual choice, the aesthetic selection was to suit the direct lyric, to articulate what was being experienced. When selecting vocal takes, I was very aware that I was listening for those that find their assimilation point at the earliest point in the wave -
those that resonated within and maximised the space that had been created by the accompaniment.

The track was recorded and mixed relatively quickly, with a rough mix completed in early 2016. Upon listening to the rough mix, I felt that the track, whilst hypnotic and mesmerising, could do more to emphasise the original intent, and so I stripped out the accompaniment in the final sections to leave just the vocal. This technique has a way of drawing the listener further into the track, and experiencing the repeated lyric in a new light, before finishing, leaving the listener hanging in the space that has been created for them.

The challenges experienced whilst recording this track were positives as they added to the awareness of the tuning and helped to focus my ears and experience further into the piece I was creating. The DAW instruments, in particular the sampled instruments, were problematic at times and prompted me to investigate work-a-rounds to have the instruments sitting where I felt they ought to. The sampled cello section, seemed to struggle with the PT tuning, with it not sitting well within itself or the track, so I tried adjusting the PT setting for the track back to in the key of E which seemed to make the tuning worse. I subsequently used a tuning plug-in and set the scale to user scale (where it had previously been set to chromatic). This alteration changed some of the melody line completely. I manually interfered at this point, not having found a pre-set option to solve the problem and after re-adjusting the individual MIDI pitches that had moved, the line sat very well.

When working with the sampled brass section, and realising that I was not having the same issues as the legato cellos, this prompted the question of whether this phenomenon was related to the natural vibrato captured in the recording of the sampled players.

I found also that whilst I was recording the vocal lines for this track of how I have shifted my focus whilst singing from quality of vocal tone to placement; looking for the sweet spot where the pitch and pronunciation sit well amidst the frequencies. I have come to identify this as the assimilation technique, which is the idea of blending and being at one not only with your sense of self but with the frequencies of the music and the environment around you. This is suggested in the lyrics of this track: “looking through”, “watching energies collide right over you” and “touching wonders beyond belief.”

When reviewing the rough mix of this track after a break from working on it for a few weeks I noticed on first listen that all pitches seemed very unbalanced to the point that I thought the settings or filters had not loaded properly. It was however my experience of them as I was listening in a different environment and after a break from listening to the track. I became aware of this as the track had settled by the bridge (TC 2:09) and I was able to appreciate the experience of the vocal overlays. Indeed, by the end of the first listen the frequencies had not only settled but were providing an enhanced experience.

My conclusions regarding the original intent of this track and the subsequent outcome is predominantly the idea of using PT as a catalyst to create more space in the track. This technique supports the idea of assimilation frequencies providing a cleaner harmonic experience. Notably, I have realised that working with the frequencies in PT has
eliminated my pre-conceived notions of good composition and enabled a more holistic approach to creating musical works.

Divine

Divine was written as a piano/vocal pop ballad. The lyrics were written first, prompted by a conversation with my father on the impact of singing the hymn: *I Am Not Worthy* as a child. In contrast, the lyrics of Divine are: "I am Divine, in every sense of the word, I have views and thoughts that deserve to be heard" (TC 1:02). A modern-day empowerment ballad, of sorts. I have always felt deeply connected to this song and have a fond memory of the writing process when a curly haired child was peering over the fence, looking through the window and being mesmerised as I was singing.

The production intent for Divine was to keep it true to the piano/vocal style it was written in. I didn't want the production to detract or overshadow the lyrical intent of the song and so focussed on getting a clean, clear and strong piano accompaniment for the vocals. The piano is joined by a simple bass line and the chorus (TC 1:02) introduces a relaxed rhythmic groove. In the later stages of production, I introduced a simple live cornet line (TC 1:45). The bugle sound added a reflective quality that added to the mental picture I held in my head of the space that this type of contemplation would occur in. As the vocal line builds at the climax of the song, I resisted the temptation to overbuild the production elements to keep the song true to its original intent.

When mixing this track, I was keen to balance a natural sounding vocal whilst also producing a studio quality track. I experimented with vocal fx and was aware of needing to re-set the auto tune filter (a standard process in contemporary vocal editing). I noted that there was a significant difference with the perfection of the frequencies between the speed to which the auto-tune kicks in. A faster response setting (78.3 ms) improved on setting the auto-tune to a moderate setting at 288ms (by improved, I refer to the degree to which the pure frequencies have the effect of going through me). A perfect setting of 0.00 ms affects the vocals with a robotic sound, so I experiment with the degree to which I can get the tuning perfection to hit as quickly as possible without audibly sounding robotic. It seems to sit at about 40.4 ms for this particular track.

I later experimented further with fine edits for the vocals using the flex pitch functionality when it became available in a later software release. I was aware that at times I was shifting the pitch of individual notes in the vocal line just for the experience of a slightly different colour, even by just edging the note a few cents away. As this track was approached in a fairly standard way, there were relatively few challenges in regards to tuning in PT.

I was aware when re-listening to the track sometime after a mixing session that the woofiness of PT was more pronounced. This phenomenon prompted me to reflect on the very standard issue of tired ears in a studio production setting. Ear fatigue occurs after long, intense and often loud recording and mixing sessions where certain frequencies, tones and affects normalise in your hearing. This can occur to the point where everything sounds great when bouncing the track but upon revisiting with fresh ears you realise you’ve not made great mixing choices. This may particularly be an
issue to be mindful of when working with PT - as through this research I have found the tuning to normalise over prolonged immersion. This is wonderful from an experiential point of view for the producer, however it may lead to poor production choices when mixing for a commercial audience.

When commencing this track, similar to others, I noticed immediately when switching from PT at A=440hz to 432hz that the first note (G) in the MIDI piano had such a depth and resonance. I am excited by just this one note and the impending recording process, to be immersed in it, and annoyed at the same time that I stopped to take notes! The diary entry captures the following:

"It feels as though the rich frequencies are beckoning like an addiction. I am continuing to listen to the track as I am typing and when the chorus hits, the previously recorded guide vox are sharp (as haven’t been auto-tuned to 432) which causes significant tension and jarring against the piano line. I feel stress headache points around the left side of the middle of the brain and around the right eye. I subsequently de-tuned the guide vox by 33 cents to bring them in line with the altered MIDI line and listening to the track again becomes addictive. The de-tune creates a robotic effect on the vocals which is a little disconcerting but completely overridden by the perfection of the frequencies going through me. They are touching my heart and getting stuck in my throat, as I write this I feel tears welling in my eyes. The track has looped and I have the same sensation with the first notes resonance. I feel my breath slow and I intuitively take deeper fuller breaths to relax into the music." (Jensen 2012 - 2017 DE257)

I recorded the live piano lines over the MIDI arrangement which provided the foundation for the track. I found this to create a muddy effect trying to play against the MIDI track which essentially created two tunings one in technical perfection and the other containing more resonant harmonics. I captured a description of this experience in a diary entry:

"It created a thick stew, which was distracting whilst I played, it was strangely disconcerting and freeing at the same time. I felt a sensation you could imagine if you were to jump into a pool of mud, that you couldn’t prevent the dirt immersing your body and so you surrender to it and allow it to envelop you. The frequencies were all pervasive swirling through my body which I was both resisting and welcoming at the same time." (Jensen 2012 - 2017 DE257)

I also had a number of experiences whilst editing the vocals for this track. In one such instance I was fine editing during a lunch break from some corporate consulting. The contrast of the environment and my mindset most likely enhanced what I experienced:

"The first note of piano resonated through me, immediately there was an instantaneous grounding and shifting of energy running throughout my body. I was aware of my entire physicality and how my body was touching the ground and the chair. The energies particularly resonated through my stomach." (Jensen 2012 - 2017 DE252)
I encountered an experience I am calling the flashback phenomenon when undertaking some fine editing on the vox double. The flashbacks seem to occur whilst being immersed in the PT experiences. It is as though the frequencies create a space which you can physically relax into, and whilst in this state, are more connected to your life’s experiences, past, present and future all at once. These flashes are fleeting, but rather than being a vision (a picture, or thought memory) they contain the feeling of the experience, as if it is being relived. It is this feeling connection seemingly created by the PT frequencies that makes the experience so profound.

In my diary notes for the flashback phenomenon experienced in Divine editing, I used the term bountiful flashbacks because they seemed to flood in thick and fast, to the point that I couldn't doubt that it was the music that was creating the space where I could reconnect with distant recollections. They were all diverse with no logical string of connectivity. I noted that there were possibly upwards of 30, some I was probably unaware of and some fleeting as if in a dream. In each instance, I was reliving what it felt like to be in those moments not just looking back at them. They included experiences such as visiting Le Mont Saint Michele when I was seven, spending time at the Prahran Market, having dumplings in South Melbourne with my parents and accompanying my father to visit business colleagues and a myriad of other life experiences. Throughout the analysis stages of this research I questioned the validity of each individual experience to the research. Does it matter what the flashback was to? In alignment with the phenomenological research approach I have included the details of flashbacks and physical sensations as they open to a line of enquiry that this research only begins to touch upon. There is hope that in further studies the relevance of whether a taste or smell or age was included in the experience becomes of deeper significance.

In conclusion, there were two phenomenological takeaways from the production of this track. The first surrounds the idea of using auto tune and/or fine pitch editing to create perfection. This process I have come to consider as erasing imperfections to assist us to create and align to the frequencies and purities that are being sought through the use of pure ratios. I felt that this was akin to a visual comparison where you might use Photoshop to enhance the colour of the sky, or increase the contrast of an image. I wondered about the application of creating a pure destination and that in doing so, it is enabling others to align to it - if we can see the end goal, how we want to be resonating, we can create it within ourselves.

The second reflection was the awareness of how I am feeling on the reviewing process of a mixed track. For example; listening to Divine in an office setting, where I may not be feeling as empowered and connected as I was when writing and recording the song. In this example, I found the song to be challenging, this struck a contrast to how I know the song can make me feel when I am more aligned to its resonance and power.

A New Song

A New Song had been in my back catalogue since 2010, had been performed live on numerous occasions, but never recorded. The piece is driven by the piano line which is an arpeggiated riff which I was keen to explore with PT. The aspiration for this piece has always been about the exploration of finding a sound or silence that represents an individual’s current state of being. The chorus is intentionally unsettling to demonstrate
the impact of not having a song or sound. The harmonic clashes match the lyrics; “that just escalate my fears” (TC 1:03)

Interesting observations captured regarding the recording process for this track included consideration of the lineal vocal line and how this enhanced or detracted from the PT experience. I felt whilst editing that the lineal melodic line failed to match the complexity and depth of the frequencies. I experimented with different effects to break up the vocal line into individual thoughts and characterise the vocal effects to give individual sentiments, such as echo, distance and pan, to match the depth and resonance of the frequencies.

I was also aware throughout the editing process that I was stretching the intervals in the vocal line to enhance the sense of PT, much like string players would throughout the late 1800's. I became aware whilst mixing this track that my production approach has changed whilst working on this albums production. I now only complete small parts of a song at a time, I will focus on improvements to a few tracks and quite comfortably leave other aspects of the song in disarray to park the song, even for weeks or months, prior to re working on it with fresh ears and feelings. This is significantly different to my previous process where I would neatly complete one song prior to moving onto the next. My observation is that once the PT frequencies have normalised and you have blended with the track, it is difficult to have an objective perspective on what needs to be fixed. I found I needed to create a space where I was listening to the track anew to ascertain what a consumer would be hearing in a radio version for the first time.

Whilst in the very early stages of producing this track, I performed the vocal in both ET and PT, and made fine adjustments to the A=432 setting to assist with vocal tone. I Instantly heard the difference and found it to be unsettling, however, by the time the verse started (TC 0:18) I had adjusted to the new frequencies. The tone was much more even, less twangy, more connected with visibly smoother wave forms and I was able to sustain notes longer. On the second take I felt energy shifting - buzzing around the back of my head.

I similarly had positive experiences editing the vocals where I felt a satisfying resonance in my ears when the frequencies were sitting perfectly. This provided a sound that pings as though it was just hitting the right places within my head. Almost all of the reflections captured for this track centred around the vocal lines, which was interesting, considering how the inspiration for recording this track was the piano accompaniment. I note that the arpeggiated piano accompaniment always sat well for this song which was perhaps an enabler for what transpired throughout the vocal recordings.

I observed whist in fine editing flex pitch that visually the vocal line was covering all frequencies and that very rarely was there a gap in the melodic line. This looked familiar to bird song frequencies which cover a wide range of frequencies rather than hitting precise points. Similar to my experience with A Love that you Own, in the final stages of mixing I decided to re-record a new lead vocal with a simplified and more grounded melody line, moving the original lead vocal to be a backing vocal.

I was also aware throughout the production of this track that I had let go of perfectionism and was able to focus on different characteristics and timbres in the track.
I had to consider whether this was a result of producing in a research context or whether this was a result of the Pythagorean Frequencies.

**Fearless**

This track was a collaboration with producer #6 who is a multi-instrumentalist and composer that began composing with microtonal scales in 1984. I first contacted this producer after discovering his web link on the Xenharmonic wiki page. As an experienced microtonalist, this collaboration was quick to start as there were no skills, system or software challenges to overcome before the producer was up and running. In the first email correspondence, he outlined applicable experience and production approach (email:080515):

"I have worked with PT enough that I could write something for your project. Primarily I'm working these days with the Ableton Live and Reaper DAWs, using ensembles of virtual instruments that can be freely micro tuned to any intonation systems required of the music at hand."

The collaboration approach was an exploration of PT in two very separate stages. Producer #6 provided some reference materials of previous works in Just intonation and 23 tone ET and similarly reviewed my previous contemporary studio releases for style. A few compositional points were clarified over email including whether or not to focus on percussion textures in the composition based on its ability to both enhance and detract from the pure experience of PT. It was decided to complete the instrumental track separately, providing the ability for vocals to be created recorded and mixed separately. There was no discussion on thematic or lyrical intent for the piece at this stage.

This producer used an Ableton Live 9 Template that he had previously established for use with Just Intonation as a foundation for the track. Prior to commencing the composition, he undertook a number of theoretical and research tasks which included the creation of a 12-tone Pythagorean interval matrix and a horogram. In his project diary he noted that:

"These are good to have on hand when composing, as they help to quickly visualize the melodic and harmonic properties of any type of alternative intonation systems." *(Jensen 2012 - 2017 DE325)*

In the initial stages of the tracks development, producer #6 focussed on sound-design, including timbres and tuning the ensemble to the intonation system. Through this process he documented that the PT thirds "lend a nice character to the harmony" and provided a detailed account of the intervals and their affects:

"Minor thirds of 32/27 @ 294 cents and 19683/16384 @ 318 cents; the latter being, for all practical purposes, audibly identical to a just 6/5 @ 316 cents. Major thirds of 81/64 @ 408 cents, and 8192/6561 @ 384 cents; the latter being only two cents flat of a just 5/4 @ 386 cents. The differences in these key harmony intervals from ED2-12, are noteworthy and very different. I personally find the whole gamut appealing to the ear, and have never had a problem with,
He commenced writing parts for the ensemble prior to compiling the arrangement and noticed, through this process, that the wolf fifth from G# to D# is audibly identical to the Hornbostel blown fifth that is used for Gamelan tunings. Based on his initial research and experimentation, he decided to use an octatonic mode subset of 12-tone Pythagorean, which offered a nice set of pitches for the main theme and harmonies with A440 Hz as the reference pitch. As part of the production process, producer #6 tuned the bass-drums to Pythagorean as they provide a harmonic anchor to the upper frequencies in the track. Prior to providing the final instrumental track, he re-rendered the individual stems and removed all of the volume envelopes and set each track at 0dB to provide more flexibility to engineer the music whilst adding the vocal components.

The process for recording the vocal lines was challenging due to a lack of clear thematic inspiration (there was not one idea that the music suggested to me) and the non-repetitive structure of the arrangement made it challenging to apply a standard verse/chorus format to the vocal line. From this, the idea emerged of a fragmented dream and the sense of a vocal line being lost within the dream and a spoken line that narrated the experience. This textual juxtaposition was further emphasised by strong use of fx in the mixing process. In my mixing notes on the rough mix I made the following notation:

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- More Fx on “wake up from the dream”
- More Fx on BV “dreams show you where you were going”
- Bridge - add a middle (lead) line to ground the bridge more
- More Fx on Bridge vox
- Make second Bridge vox an echo
- Reduce volume of sung vox to no louder than the spoken verses
- “Find a way to find” rhythm needs to be better aligned to the 12/4 arrangement”
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When I first received and listened a few times to the instrumental track, I found it to be quite unsettling as though pulled in too many directions at once. I was aware of energy shifting in my lower abdomen and rising to my throat making me feel nauseous. This experience lessened as I connected the thematic content to the track which provided an outlet for what I was experiencing both through the narrated components and the vocal lines providing the sensation of being trapped.

Whilst in the process of recording the vocal lines I became more connected with the complexities in the track and in an email to producer #6 provided the following dialogue (email:040615):

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“I love the rich atmospheric conditions that you’ve been able to create by complimenting the Pythagorean Frequencies with timbral rhythmic elements that also seem to have a leaning to the same qualities of resonance as PT tones.”
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Through the mixing process I was less aware of the initial responses I had to the track. I observed that when I listened to the song through car speakers (a good mixing technique to test the mix quality on lesser quality speakers) that I was more aware of the tensions within the track on a morning trip than an evening trip. I was contextually aware that
after a fast paced and stressful day that the fluidity of both the rhythmic and melodic elements is more aligned to how I am feeling than it was in the morning when I was in more of a natural state. This is significant to this research as overwhelmingly the Pythagorean Frequencies have tended to be more aligned to my natural state, however the arrangement and complexity of this track created the opposite effect.

**Without a Nest**

This track is a self-produced, original track which commenced studio production in March 2015. The song composition commenced with the piano riff, which as I composed this on the PT piano, I found it became a meditative process to play as a warm up in all of my piano sessions for many months. I was often drawn to play the piano line without the vocal and whilst repetitive in nature, found experimenting with the riff in various octaves would provide added interest to the song. This can be heard as a feature in the final produced track with the higher octave piano line featuring in the last two verses and outro of the track. In a traditional pop context, this song feels unfinished as the song is in strophic song form. There is no contrasting chorus or bridge and the instrumentals between verses reiterate the same melody throughout the verses. Whilst the final two verses vary slightly in the melodies of both the vocals and accompaniment, these variations were composed to support the thematic content and enhance a sense of reflection on the lyric rather than from a need to vary the arrangement to suit a stylistic need.

The strophic song form suits the thematic intent of the lyric which is essentially an exploration and declaration of a personal need to continue to push boundaries and not be confined to pre-conceived notions of what life should or could be. Ideas such as “fly into the storm” (TC 0:40) and “without a branch to stand on” (TC 1:17) lead to a sense of drive and purpose to “fly through the raging heat” (TC 1:24). In the third verse, the lyric explores the benefits of these drastic measures in being able to “spread my wings” (TC 1:54) to reach “lands that are unheard of” (TC 2:02). The final two verses (TC 2:20) recapitulate these benefits, with a change from first person narrative to a more directive declaration to listeners.

The process for recording this song started with the piano line in MIDI which had been created in the music notating software, Sibelius. In the final arrangement, this part is undertaken by a software string section which features in the introduction and interludes. A live violin take was recorded also, but not used in the final mix as there was more richness provided by the software string section, which was enhanced with a Glide function to make them sound more lifelike. When recording the live violin line, I experimented with different hand positions on the violin, which resulted in an awareness that the resonance of notes on the open strings created the greatest ping to feature the frequencies. The piano part was recorded live on the PT piano and was separated into two lines, a melodic line and a bass riff. When commencing the recording of the live piano I set the project settings to A=432. I noted in my diary entry that the MIDI didn’t sound great in ET but when I set the project to PT, set with the root note in A to match the composition, I observed two attributes. Firstly, I found these adjustments enhanced the PT experience, that there was a richer quality that had more depth and resonance and secondly, that the MIDI arrangement blended better with the acoustic piano feel. Other instrumentation is kept to a minimum to feature the original repetitive
meditative melody. There is a combination of light rhythmic synths throughout the track and a live cornet line in the introduction (TC 0:02) which provides a grounding, earth element, prior to the vocal line commencing.

The recording of the vocal line was interesting as the slow nature of the vocal line exposed the frequencies and the qualities of each note within the vocal line more than other tracks. At the final mixing stage, I decided to re-record the lead vocal as some of the original lead was sounding over-edited and I was aware that the most recent updates to the logic software would provide easier and more accurate editing of the vocals than was originally available. Whilst the vocal line uses the function; set all to perfect pitch, there are some notes that I edited just slightly away from this to audibly sit where I felt they should; such edits included storm down 11 cents (TC 0:46) and wondering why down 11 cents (TC 2:13).

I also observed large variances in the frequency ranges of sustained notes in the vocal line which contained large amounts of vibrato. Many of these notes I reduced the vibrato in the vocal editing process to provide a more contemporary sound and a purer alignment of the Pythagorean frequencies. One such example is the word Life (TC 3:08) where the vibrato range was over 400 cents. I observed that many of these vocal waveforms in this track have a visual similarity to bird wave forms which cover a wide range of frequencies from the start to the end of a note. Some of the words cover up to 300 cents in smooth unbroken pitch bends. I contemplated the performance aspects of this phenomenon and considered that perhaps having a perfect resonance as a landing note, the singer is enabled more freedom to apply emotive tools such as being able to sing through the consonants prior to landing on the perfect frequency. This is an area of enquiry that could be pursued in a more focussed study with a sample group of many different singers exploring a comparison of ET and PT wave forms.

Regarding production elements, the vocal line features a high degree of automated effects (such as echo and delay), particularly in the last two versus. This is another technique used to provide variance and interest to the strophic song form and add to the ethereal nature of the lyric in the last two versus. This is thematically appropriate as the end of the song is less about self, rather it contains generalised reflections and guidance to the listener.

I captured in a diary entry when listening to one of the mixes through headphones whilst focussed on other activities:

“I found the track to be mesmerising, it had a lilting quality that propelled me almost into a daze which I had to snap myself out of it to capture the observation.”  (Jensen 2012 - 2017 DE329)

In conclusion, this track was afforded external validation as it was selected by a music industry professional as one of the three potential singles from the album.

Our Mission

This collaboration was initiated in May 2014 when a mutual contact (a film score composer) introduced me to producer #3, a fellow film score composer with an interest
in micro-tonal music. His interests include alternative tuning systems in film score compositions to create enhanced aesthetic experiences for audiences. Due to scheduling commitments, the collaboration was delayed until February 2015, and was completed in February 2016.

At the first meeting, the conversation focussed on the research findings to date and the inspiration that drives each of our compositions, particularly with regard to applying non-standard tuning to enhance the experience of the listener. We discussed thematic drivers prompted by the question; what do I have to say? We discussed ideas such as embracing change and life challenges and doing so without fear of failure. The conversation was driven by an understanding that in the producers’ words “The only thing that matters is what you’re doing and how you’re evolving.” (Jensen 2012 - 2017 DE242)

Prompted by the conversation, I shared a mission statement that I had written (unconnected to the research project, or music) that encapsulated the sentiments we had discussed. Producer #3 advised that his compositional process was very much guided by being immersed in a range of inputs prior to commencing any musical creation. I provided a range of previous releases acoustic recordings, other PT collaborations and the PT carols to assist this producer in this process.

After being immersed in the reference materials and having some time to contemplate a possible collaboration, we met again and discussed the likely influences that could be included in the composition. We discussed the idea of blending and fusing different styles that would incorporate a range of colours into the piece. We discussed at length, differences in western and eastern musical influences (notably that middle eastern octaves are stretched). We discussed the PT carols that have middle eastern music influences in the accompaniment. We considered the concept of western music needing to resolve and how this may have played into the strong rhythmic characteristics that have become a feature of my Pythagorean compositions to date.

From this conversation, we landed a stylistic starting point which would be a slow Pythagorean track with middle eastern samples. The track would be comprised largely of spoken sections, possibly incorporating some male hip hop components. Following this session, producer #3 sent through a sound file example of a track incorporating middle eastern samples.

To progress the track, producer #3 requested that I record a spoken version of the Mission statement that we had originally discussed. I experimented with the pace and rhythm of the spoken text and decided to use a click track to give the words more structure and provide a neater sound file to work with. Producer #3 requested that I re-record the spoken text at a very slow pace. I provided a few options including a version that was a third longer than the original and an improvised sung version nearly four times as long as the original. The sung version has no key or melodic structure and was performed using my inherent tuning, that is, I had no reference accompaniment to sway my pitch to either ET or PT. To perform in this way, I allowed each word to guide where the next pitch would land. Segments of this recording are interspersed between the spoken sections of the track and are layered and affected to achieve thematic and timbral effects.
Producer #3, provided the following summary of the completed composition:

"Built on a 12-tone row as the functional harmony, the piece follows a slow evolution from fragmented, elongated textures to melodic movement through the same tone row later in the piece. Set in alternating 9/8 and 11/8 time signatures, the turkish cumbus and synthesisers interplay sweetly as the backdrop to the vocal line, sung. The texture is at once peaceful and smooth, as the sung lines of the introduction to the speech coincide with. The vocal is heavily affected with delays, reverb, granulisation and distortion to set the tone, as well as for experimentation.

We then receive our first clear introduction of the spoken word after this initial text setting is complete. The repeated tape looping and abstraction functions as a counterpoint to the simple spoken word, and builds, with the introduction of a heavily affected piano, to the next section. The spoken word itself is fragmented into several divisions, and so I thought it fitting that the piece be divided as such. This section is mainly to give focus to the subdued tone of the spoken word.

A violent, electronically distorted and filtered sample takes us into the chaotic section, which features the reintroduction of our 12 tone row, accompanied with rhythmic figurations, on the cello. The spoken elements take a backseat to this repeated figure, to show the necessity for total overhaul in thinking required for change, which the spoken piece specifically focuses on. This section features a disorienting spin on the vocals, that occupy stereo space for the true enveloping feeling.

Finally, we enjoy a full presentation of the speech, with sung lines reconfigured into contrapuntal lines and repitched and doubled for a full chorus (community) feeling. Finally, we leave the listener in quiet reflection for the thoughts presented in the piece." (Jensen 2012 - 2017 DE324)

My experiences and observations listening to Our Mission have been valuable to this research as the composition has a number of variances to the other more commercial tracks in the project. I am particularly aware that the sung and spoken elements come together quite seamlessly to the point that I would be unable to recount which sections and how much of the track was using which technique. I also found that similar to the experience of fine editing vocals in other tracks I experienced the phenomenon of flashbacks just by listening to the final mix of this song.

I considered one of these experiences in depth, which was a flashback to my sister performing in an Australian play when I was in Primary School and she in Secondary. I was fascinated by this flashback as, like so many of them I am completely unaware of the thread that connects the sound experience that has triggered me to recall this play. I am aware, however, that it is being immersed in the sound that is triggering the recollection; there is a feeling of being taken back to that moment in time but the feeling is as though I am an observer of myself in that moment, not that I am myself in that moment.
This concept of the flashback phenomenon has raised the consideration of influences in musical creation. Especially the idea that influences are broader than just the sounds or thematic ideas being woven into artistic creations. Rather, influence is the essence of your feelings, and from various times in your life these feelings have been captured in, and are replicated through, sound experiences. A practical consideration of this might be the legal repercussions of plagiarism, where artists inadvertently copy a riff or musical idea. If the sound and a feeling are linked, an artist may be replicating a feeling that results in a copied sound but unaware that it is a copied sound as it was inspired by a feeling.

Throughout the collaboration, producer #3 also captured some observations including an experience of listening purely to PT for two to three weeks, and then finding it difficult to come back to ET. The impact of this was that it was then difficult to re-adjust back to ET to complete a film score, he noted that it took two days or so to adjust back. He also took the opportunity to play PT scales to third year composition students who said: "No, it doesn’t sound out of tune, it sounds ‘relaxed’." (Jensen 2012 - 2017 DE325)

Re-imagined Christmas Carols

When commencing this research, I experimented with PT in a number of applications, live, digital, acoustic, originals, covers, and various styles of music including chanting and improvisation. To explore the creative components of the study I was drawn to two avenues of enquiry, the first being the original compositions, collaborations and productions. The second was the application of PT to Christmas carols, many of which would have originally been composed and performed using natural tuning. Using Christmas Carols provides a range of interesting avenues of enquiry to this study, including:

- Compositional variances across many centuries
- Familiarity of the tunes to listeners
- Shared thematic material across many of the tracks
- Varied stylistic interpretations and arrangements already available (providing no expectation of how they should sound)

The Carols have all been self-produced and have provided somewhat of a testing ground for production techniques on the original compositions. The Carols have been released progressively throughout the six years of research, one release in 2011, two in 2012, four in 2014 and six in 2016. The increase in tracks at each release point demonstrates the level of confidence producing the carols and working with arrangements in PT. I became clearer on what I wanted to achieve through each of the tracks as the project progressed.

In August 2014, I was on a performance tour in Perth, Australia for 10 days. The tour bus provided lots of time to work on arrangements for the 2014 releases and consider stylistic choices for future carols. At this time, I captured a summary of the aspirations for each of the carols. I considered the stripped back melodies, harmonies and thematic material of the songs before considering a possible style that I thought would be
interesting to explore through the track. Most of the final releases stayed close to the original intent, with some varying slightly as the productions evolved.

For the first three carols that were released I created release artwork that was eclectic in nature, using many filters to visually demonstrate the carols were re-imagined and not traditional arrangements. I also selected a base colour for each release which provided contrast across all the songs when completed. For the first few tracks the colours selected are traditional Christmas colours of red, green and yellow. When reflecting on the stylistic choices for the tracks, I also considered what base colour I was drawn to for the arrangement. This is of interest to this research due to the plethora of materials linking colour and sound frequencies. The table below provides a summary of this information.

<table>
<thead>
<tr>
<th>Release Year</th>
<th>Title and Acronym</th>
<th>Intended Style</th>
<th>Intended Colour</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td>God Rest Ye Merry (GRM)</td>
<td>Celtic</td>
<td>Red</td>
</tr>
<tr>
<td>2012</td>
<td>Holly and the Ivy (HI)</td>
<td>Indie</td>
<td>Green</td>
</tr>
<tr>
<td>2012</td>
<td>Silent Night (SN)</td>
<td>Ballad</td>
<td>White Yellow</td>
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<tr>
<td>2014</td>
<td>Angels from the Realms (AFR)</td>
<td>Folk</td>
<td>Gold</td>
</tr>
<tr>
<td>2014</td>
<td>Coventry Carol (CC)</td>
<td>Techno</td>
<td>Grey</td>
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<td>2014</td>
<td>Midnight Clear (MC)</td>
<td>Beatnik</td>
<td>Baby Blue</td>
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<tr>
<td>2014</td>
<td>O Holy Night (OHN)</td>
<td>Gospel</td>
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<td>Away in a Manger (AM)</td>
<td>Lullaby</td>
<td>Earthy</td>
</tr>
<tr>
<td>2016</td>
<td>Deck the Halls (DTH)</td>
<td>Dark</td>
<td>Dark</td>
</tr>
<tr>
<td>2016</td>
<td>Ding Dong (DD)</td>
<td>Trance</td>
<td>Orange</td>
</tr>
<tr>
<td>2016</td>
<td>The First Noel (TFN)</td>
<td>Tribal</td>
<td>Green</td>
</tr>
<tr>
<td>2016</td>
<td>We Three Kings (WTK)</td>
<td>Baroque</td>
<td>Purple</td>
</tr>
</tbody>
</table>

Figure 7 - Christmas album summary

The approach for recording each of the carols was similar, starting with a MIDI file of the traditional melody and adding instruments and harmonies to suit the style in which I had intended for the track. I would generally record a guide vox early in the process to guide the development of the production. Many of the tracks include doubling of melodies on varied instruments to suit the style of simple, strophic song form (GRM, WTK, MC). Others suited a sparser arrangement without rich instrumentation layering (AFR, MC, AM, SN, CC) some of these tracks tend to have more rhythmic features to add complexity and interest to the arrangements.

In my procedural notes for the development of the carols, most of the dialogue is neutral of temperament. Production notes include; selection of fx (DTH, DD, TFN, WTK) automation (DTH, DD, TFN) and adding colour to arrangements with extra interludes and beats (CC, DTH, DD, MNC, TFN).

At the mixing stage for the tracks, I noted comments such as for DTH: “The mix is sounding a bit muddy, none of the features are standing out” (Jensen 2012 - 2017 DE326). And another example from MC: “The intro needs to sound less like MIDI and the vocals are sounding too aggressive in the mix” (Jensen 2012 - 2017 DE327).

I experienced a range of challenges relating to pitch on five of the tracks, specifically in my perceptions and responses to working with PT. In TFN I found that the world instruments struggled to be in tune with vocals even with auto tune on both channels.
After trying to remedy this for some time, I found it too difficult to resolve and deleted the track containing the world flute software instrument.

In AFR I captured that the backing sounded flat when recording the vocal and hence, in trying to compensate, the vocal was quite sharp. To remedy this situation, I tried holding the microphone to be more connected to the song, but was aware of how unsettled the pitch was resonating within me at that time and it was affecting my vocal performance. I used global auto tune on the track but found the sound in the headphones was still sharp. After I muted the track and recorded the vocal without monitoring I found that I enjoyed it more and noticeably felt energy shifting in my abdomen. I also noted that the bass guitar sample seemed to be “bending and is wobbling being shifted by the PT” (Jensen 2012 - 2017 DE212).

I realised when recording the backing vocals for AFR that the track had been recorded in ET rather than PT. When I changed the track to PT and listened to the sequenced track without the vox, the track was more balanced and the guitar didn’t seem flat. I listened to the vox which still seemed sharp but not as bad. As the track had been detuned to A=432 I adjusted this setting and landed on using A= 434.9.

Producer #2 from the original collaborations assisted with the mixing stage of the 2014 carols release. We discussed what had occurred with the AFR track as it was also experienced in aspects of the OHN mix. We considered how the sampled instruments would have been recorded in ET originally and the timbres of some instruments would respond differently to the processors. An added consideration would be the fx used on the channel strip such as chorus and echo that would add to the instability of some of the software instruments.

Similar challenges were documented for the MC recording process where I found that I had to mute the track monitoring whilst recording. I captured that the “lower pitch of the song (the C#) is making the natural re-verb echo resonance too distracting to sing with.” (Jensen 2012 - 2017 DE197) Upon first listening to this track, producer #2 commented that the intro guitars sounded out of tune but when the vox come in (TC 0:12), it settles. To try and minimise any of these nuances we changed the default A=432.2hz in fine tuning to 432hz (a manual override as the adjustment to 432 automatically adds the .2).

The challenges captured for CC relate to the pitch perception experience of working with a rhythmic track. I noted that the drum and bass arrangement made it difficult to place the vocal line melody and subsequent layering of harmonies. The harmonies are the original notated notes from the 16th century. It is interesting to note that in this arrangement, I selected not to use the traditional Picardy third (a major third in a minor context). This was not an intentional choice to remove the cadence (TC 0:39), rather it seemed not to suit or work with the arrangement. In lieu of this traditional resolution and to suit a more modern production style, the last 40 seconds of the track (TC 2:00) repeat the chorus on loop and fade similar to many contemporary pop songs.

There were a number of challenges with the vocal recordings for OHN which resulted in a third vocal re-take. I found that working with the accompaniment was not producing the vocal that I wanted. In part I believe this to be the arrangement, including
a contrasting rhythmic beat and a synthesised melody which work well with the vocal in
the final track but were not conducive to supporting the vocal performance whilst
recording. I tried to track the vocal with just a click track to explore this challenge,
whilst I “kept steady pitch, I was slightly sharp” (Jensen 2012 - 2017 DE203) and the
take wasn’t sitting well with the groove so it wasn’t used in the end.

The PT experience for some of these tracks had a similar challenge to some of the
original tracks which was remedied by changing the key setting for PT in Logic. I found
that whilst arranging a track that the F’s in the base line weren’t sitting comfortably,
which prompted the shift. It is interesting to note for the purposes of this research that
this challenge was only experienced a few times and not all tracks have the root key
established in the PT settings. It is also of interest that it was always a particular note or
software instrument that prompted this change in the settings, and the remedy, whilst
subtle, always resolved the issue.

Whilst recording the Christmas Carols I experienced a range of hearing and physical
responses regarding the PT pitches. I captured a lot of examples of Flashbacks and with
the 2012 release, SN where adjusting the track from ET to PT I captured:

“Straight away I was aware of the side of my back mid-way down, I felt a wave
of relaxation and became emotional.” (Jensen 2012 - 2017 DE123)

Regarding my pitch perception when editing AFR, I was aware that shifting a pitch by
one or two cents (whilst lower perception than JND would usually warrant) I observed
that the note still changes in colour.

There were four carols that I realised in the editing process that I had recorded the
vocals with the tuning for the track set to ET and not PT (AFR, AM, TFN, WTK). This
occurred as I would start each track in ET and adjust them sometime during the creation
of the arrangement to provide a comparison of the track in the two tuning settings. As
the tracks were developed over many sessions, I had assumed that they had already been
adjusted. When I did adjust the track to PT, immediately the vocals sat better within the
accompaniment than they had in ET. I captured that they were:

“Smother and less jarring, even the timing seemed to be affected by the senses
of resonance coming from the PT frequencies in the accompanying tracks.”
(Jensen 2012 - 2017 DE251)

This is interesting to the research as it exemplifies the idea of inherent tuning for
singers, string players, and other instruments without fixed pitch.

The other concept prompted by the carols relating to pitch is the idea of a well-known
song already having an inherent pitch frame of reference. I wondered when recording
the tracks that I have sung for many years, whether this learned and ingrained tonality
would appear in the tracks. I was surprised listening back to some of the soloed vox
recordings where I had accentuated different notes and intervals to those that I had
traditionally been used to singing.
Flashbacks were captured whilst working on five of the carols. Whilst editing AFR, I experienced a lot of unconnected flashes, including being in a swimming pool that was chlorinated, the feeling of the first warm day of spring, my grandfather, being at the airport and a holiday to Noosa. I captured that there was a feeling of experiencing connectedness with these flashbacks. When fine editing the vocal line for AM, I had a flashback to being at Le Mont Saint Michele in France when I was seven and memories of my grandmother. When I was editing the vox double for DTH, I experienced a flashback to a school camp at the beach.

Whilst editing DD, I experienced a different kind of flashback, rather it was more of a flash forward to a range of life aspirations. They were to places I would like to go, there were many luxury experiences, "gourmet foods, festivals, fine food and lux experiences" (Jensen 2012-2017 DE319). What is interesting about these flash forwards is that they were all sourced from experiences as a child but in the moment had a future focus. Again, a sense of connectedness of recalling experiences, and shaping and creating future experiences based on previous moments. All facilitated by being sustained in the PT frequencies in present time. An example of this was a flashback to Elgie park (a winery in Red Hill, Victoria) which was both a flashback and an aspiration to be there in the future.

There were many, varied and interesting flashbacks experienced whilst editing different aspects of TFN, including a holiday to Thailand, a visit to where my grandfather grew up and other childhood holidays. There were many flashes to places I’d like to go now, and ideas for future outings. All these flashes aligned to the same feeling of experiencing life and especially experiencing diversity in life. This is of interest on this track in particular as it has an aspiration of being tribal and incorporates a number of world sounds and samples.

When syncing the various vox tracks (lead, double and low harmony), I experienced the same flashback and flash forward scenario. However, this example had a multi-location as well as multi timeline paradigm. The flash was of the feeling of being in Harrods in London in the future (which I visited at ages seven and eighteen), but was combined with a feeling of being in a similar department store in NYC (visited at age 23) at the same time.

Whilst capturing these in-depth reflections mid-way through the editing session, I was aware that the observations ceased throughout the following 30 minutes after capturing them. Once back in flow, after stopping to enter them in the research diary, extra flashbacks came flooding in; including a visit to my father’s cottage in the bush in the 90s and a flash back to Holland that we visited in 1986.

Other hearing and feeling experiences captured whilst working with the carols included the following:

- Finding some of the alien sounds in CC (TC 2:04) to be quite piercing when listening to the track through a wifi speaker (Brand: Solemate).
- Finding the synth sounds in DTH (TC 0:18) to be far more piercing in my ears than other sounds.
• Feeling a numb buzz above my right eyebrow approximately ten minutes after listening to GRM.
• Feeling a ping in my neck when producer #2 made a sudden EQ shift whilst mixing OHN.
• Feeling an intense pin point in my left foot one inch towards my heel down from where the little and second toe connect whilst listening to the bass track soloed in AFTRG.

Additionally, I captured a number of in depth phenomenological experiences whilst editing TFN. Whilst fine editing the harmony on the word *great* up by ten cents (TC 2:35), I experimented with the JND of this pitch. I first tested five cents then, eight, ten and twelve. At ten cents, I observed a crackle in both ears, the crackle was most significant at twelve cents, however at twelve, the pitch had gone too far outside JND, so returned to ten cents where there was less of a crackle than previously. As I captured the observation I felt a settling occurring in my ears with the energy adjusting down the Eustachian tube in my right ear. This concept of shifting pitches for timbral effects opens the question as to whether a resultant tuning system is the result. However, in all instances where an adjustment was made, it was to an isolated melodic line, such as the vocal, and not to the harmonic structure of the piece.

As I continued playing the full mix, I was aware of buzzing around the bridge of my nose which was a usual experience on prolonged mixing immersions in PT. I also experienced the sensation of wanting to stretch my chest cavity as though there is not enough room for the muscles to expand to their full capacity. This was accompanied by correlating sensations under my shoulder blades with these muscles twitching and trying to stretch.

I left the track playing whilst capturing the experience in the research diary and felt the integration of the frequencies with my physical self. Some of the buzzing around the facial meridians eased, but in parallel caused a nauseous feeling due to the prolonged listening/experiencing. I am also aware that the nauseousness seems to accompany the lower frequencies and eases as the frequencies are higher and lighter.

Whilst mixing TFN, I changed the Cello to an Indian Shenai Oboe to give the track more of a world sound. I am aware that the resonance of this instrument has a strong vibrato and I am “feeling the sound resonate as pulsating waves around me” (*Jensen 2012 - 2017 DE250*). Additionally, I noticed the need to surrender to the strong vibrato. I experimented changing the setting to ET to see if this effected the vibrato of the software instrument. The whole track immediately sounded thinner and brighter as though the music were “sitting on top of an ocean and not part of the depths below” (*Jensen 2012 - 2017 DE250*).

In conclusion, the Carols project has provided a plethora of observations and experiences working with PT that I wouldn’t have otherwise experienced just undertaking the collaborations on contemporary original tracks. I considered the vast array of physical and mental experiences captured through this process and wondered what impact there is on the experience of PT when compressing into MP3 format.
I was aware that I seemed to have a compositional preference to keep the carols predictable, especially when I was recording the double vocal for TFN. Whilst the tracks may seem significantly different in their production style from their traditional versions, many of the melodies, harmonies and arrangements are very true to the originals with the production providing the re-imagined element.

Finally, I played GRM as part of a research presentation at a conference in Queensland where another researcher got defensive about their musical sensitivity to PT "Oh, I could tell the difference" (Jensen 2012 - 2017 DE329) in response to others saying that they couldn’t. This prompted the idea that we have become so ingrained in our thinking and musical education that ET is right, that we as musicians have reinforced this sentiment with our perfectionistic competition and ego.

All of the wondrous experiences that have occurred whilst re-imagining these carols would not have been possible if I wasn’t open to the spaces in-between to experiment and trial and be open to imperfections and unpredictable outcomes. Many of the challenges experienced in recording these tracks in PT would be minimised with more production experience in PT, more training available and shared knowledge on what the obstacles may be. The experiences and/or benefits of the physicality and mental connectedness can only be enhanced by more undertakings and time spent working with the frequencies.

**Alignment of Learned and Researched Experiences**

**Participating in the Experience**

Throughout the phenomenological exploration, and literature review, I became aware that the benefits of PT are dependent on the flexibility of the artist and audience to trust, explore and relax into the frequencies. This trust requires the willingness to move away from perfectionistic pitch and to surrender to the experience rather than operating with a default, learned or logical response. Ball discusses this concept purely as what people have become accustomed to and that any opinion on which tuning system is best will always be driven by previous experiences (Ball 2010 Pg62). Duffin takes a more extreme view of our tuning preferences referring to the; “decades of delusion, convenience, ignorance, conditioning and oblivion” (Duffin 2008 Pg16)

I have found when experiencing (creating, playing or listening) PT you need to consciously and proactively relax into the experience. If you only hear with your ears, you're not getting the total body experience. When commencing this research, I assumed that any benefits from PT frequencies would be due to a form of sympathetic resonance. I thought that if you were in their space you would be affected by them independently of any conscious choice. However, over six years of exploration I have concluded that the benefits of PT are enabled by your conscious choice to participate in the experience.

Reimar and Wright refer to a thesis that is built on the idea of "music is what I am when I experience it". The thesis similarly argues that music is not just auditory, it is a "synesthetic perception and thus a bodily engagement with sound.” They discuss how
the experience belongs to those who are intentionally involved in it with a willingness to participate. The participation in musical activity has a requirement to consider "time, space, play and feeling" (Reimer and Wright 1992 Pg55,59).

They also refer to the need for open-mindedness, referencing the avant-garde trends of the 20th century (Reimer and Wright 1992 Pg47). In the context of this research open-mindedness prompts the question as to whether listening to PT is as big a stretch as we have asked listeners to appreciate music in other ways, such the unpredictable nature of avant-garde?

At the other end of the spectrum of openness and participation are of examples of intellectual appreciation only. At the extreme end, in his book Musiciking: The Meanings of Performing and Listening, Small refers to musical performance as one-way communication where the performer is only a medium of translating the composer’s intentions to the audience. He continues to describe the role of the listener purely to contemplate the work but the role of contributing to it lies solely with the composer, not even the performer! (Small 1998 Pg6)

These perceptions have changed over time in alignment with varying styles of composition which has influenced our willingness to participate. The historical timeline provided as part of this research is significant in this concept as the idea of social climate and accepted norms influence our behaviours. For example, the financial markets, political instability and social exploration all provide various cultures. When considering the move from PT to ET, it is quite possible that the need for equal was influenced by a need for control, a need to understand, or a need for perfection. This prompts the question; are these still our needs today?

The extreme view of Duffin referenced earlier, the conditioning of ET, has been evident throughout this research, and I have deduced that there are many needs that could be met through an open-minded approach to experiencing alternative tunings. During this study, I attended a research presentation by Richard Parnutt, author of Harmony: A Psychoacoustical Approach and enquired if he had tested the study with alternate tunings. His response was (close to verbatim):

“I’ve not been concerned with tuning or temperament. A musical interval is not a ratio; it is a distance between two pitches. We could re-run the experiment, and ask 50 people to waste their time testing other tuning systems, but it would unlikely make a difference. It’s well documented that if you listen to renaissance choirs the one that is singing closest to equal temperament will sound the best.” (Parnutt 260215)

Hearing v’s Experiencing

Taking the concept of participating in the experience deeper is the idea of whether we hear music or we experience it. This concept can be described as the depth and breadth of musical explorations. Each new temperament that has been created is an exploration in breadth, and uses mathematics, hearing and psychoacoustical exploration; whereas a study in depth looks at a tuning system in its entirety, exploring its effect on the human experience.
Reimar and Wright describe a genuine musical experience requiring a range of non-musical aspects that they refer to as impressions. These impressions include the ability to recall, imagine, anticipate events, and be aware of impulses (Reimer and Wright 1992 Pg81). This concept is significant to this research considering the flashback phenomenon that has been experienced as part of the practice led components.

Reimar and Wright also refer to an earlier concept of musical perception that Hindemith borrowed from Saint Augustine's De Musica which demonstrates a much narrower view of this topic:

“1. The physical fact of sound.
2. The faculty of hearing.
3. The ability to imagine music without the actual sound stimulus.
4. The ability to remember previous musical experiences.
5. The ability to intellectually examine and judge musical shape and grade.”
(Reimer and Wright 1992 Pg80)

It is perhaps Cage's work 4' 33" that has inspired more creative and philosophical contemplation on the experience of music than any other topic. In his book, Themes in the Philosophy of Music, Davies talks of the original audience misinterpretation that the function of the piece was to explore silence. Rather, the value of the work is highlighting the environmental sounds in and around the performance space and encouraging the audience members to experience them (Davies 2003 Pg4). According to Davies, the premise of Cage’s work was to explore “sounds not intended” (Davies 2003 Pg12). This is an interesting concept in the context of this research considering the wolf intervals created by non-tempered tuning systems and the flex in tonality that is created when working with frequencies that are close but not entirely perfect. When working with pure ratios, it cannot be assumed that they will be 100% pure, all of the time. Especially when using a range of instruments, technologies and sound environments. Within a PT experience there will be many sounds not intended.

When accepting and surrendering to the whole experience of music, we become increasingly aware of our physical and emotional responses. In his book Biomusicology, Wallin considers whether the emotions that accompany music are in music, created by music or external to music (Wallin 1991 Pg235). Throughout the phenomenological enquiry in this research I have considered that the PT frequencies create a space for the experience to occur. Specifically regarding emotions, I would argue that it is all three, the emotions that may be external to music, are triggered by the music, but are also somehow contained within it. The frequencies connect you with aspects of yourself that you may not have otherwise been able to access without their resonance aligning to and awakening aspects of your resonance.

Likewise, the physical aspects of the whole experience of music can be considered in a similar way. Is a physical sensation caused by the vibrations, is it triggered by it, or is it pre-existing? Throughout this study I have especially contemplated what role the sounding boards in the body play, for instance; the chest cavity, sinuses and mouth. I have asked the questions; How is our physical experience comparative to the vibrations of a tuning fork? How does the periodicity of sound interact with the periodicity of
bodily functions such as our heart beat? How do the sound waves interact with the different components of our physical self, such as fluids, tissue and bones?

Similar to emotion in music, I have considered how the PT frequencies create a space where the natural vibrations of the human body are invited to align to their resonance. A buzzing sensation, therefore, may be induced by the difference between the natural vibration and the sound wave vibration making its way through the body. A sharp jolt or pain may be where the sound wave is blocked by one part of the body. In this way, I have come to understand through this research that the pure ratios act as a form of conduit and as such have referred to them as Assimilation Frequencies.

Evolving Experience Over Time

Throughout the phenomenological enquiry in this study, the concept of time has played a significant role in what has been experienced. This concept of time has held a number of avenues of enquiry, including the following:

- Longitudinal awareness, experience of PT over six years
- Period of immersion, i.e. five minutes versus eight hours
- Repeated exposure, daily practice periods
- Societal timeline, concepts and beliefs ingrained over centuries

Each of these dimensions of time have been explored through live performance and practice, recorded experiences and with collaborators. Most significantly, I have observed how the first note you play in PT takes time to waft and settle, and how after eight notes or so there is alignment to the physical self, a sense of tuning the instrument (the body).

Ear cleansing is a tool used in the acoustical profession, techniques such as a day of silence or focusing on different sounds or keeping a sound diary are all common practice. I have contemplated how these ear cleansing techniques would operate to reset the ears after periods of immersion in different tuning systems. I have also considered the role that PT plays in being its own ear cleansing or as a further concept as body cleansing.

Throughout the literature review, a number of authors were found to discuss the concept of experiencing PT or ET over periods of time. Duffin refers to the paradigm in the 20th century where musicians have become so conditioned that they think and hear in ET to the point that everything else is considered out of tune (Duffin 2008 Pg17). Ball quotes Helmholtz as saying that ET is “unpleasant to uncorrupted ears” implying that there is a process, a duration for which the ears become corrupted (Ball 2010 Pg61).

Gann discusses on his website the concept of immersion in just intonation over a couple of weeks and the experience of ET following the immersion, describing it as “insipid, bland and colourless”14. He further describes the return to ET as a disappointing readjustment, as though seeing the world in black and white after a period of full colour.

14 http://www.kylegann.com/tuning.html
Godwin provides a buddhist quote that Cage draws on relating to time; that if something is boring keep doubling the amount of time you try it for until you find interest in it (Godwin 1987 Pg24). I would suggest this also as a technique to normalise alternate tunings after being conditioned to any one system.

Composition

Godwin provides a quote by Grieg that prompted consideration of the role of composition in enhancing the PT experience: “we composers are projectors of the infinite into the finite” (Godwin 1987 Pg75). Throughout this study I have explored the difference between musicians (singers and improvisers in particular), who have finely tuned their physical whole of body connected awareness versus those that compose and devise new scales purely from a mathematical and theoretical perspective. A third category would be composers whose compositions are an aesthetic auditory experience without consideration of either the whole of self or theoretical perfection. All three approaches are affected by using PT and affect the PT experience for listeners.

Throughout the practice led activities in this study, whether I was experimenting theoretically, aesthetically or connected to the experience it was the idea of simplicity that resonated most profoundly in my compositional approach. Some of the compositional techniques I became aware of included:

• Stripping complex chords
• Using spoken vocals to enhance simple chord progressions
• Repetition
• A preference for verse format
• Focussing on rhythmic elements to enhance purity in frequencies

I documented this preference for simplicity as an indication of how PT is “self-contained beauty” and compositionally how PT music “fits nicely within itself” meaning that pure ratios are perfection in their cleanest form (Jensen 2012 – 2017 DE330). I also noted that much of the music composed when PT was the prevalent tuning system held many of these compositional characteristics.

Heller highlights this by questioning the value of changing temperament to match musical style. He points out that in faster music, the temperament is less of a concern as there is not enough time for beats to occur:

"It is a matter of opinion whether the loss of perfect fifths and fourths using ET is worth the gains in compositional freedom...” (Heller 2013 Pg526)
Accuracy

Throughout this study, the concept of accuracy has been a consistent theme both in the literature and practice led components. The questions prompted included: Can we hear the accuracy of pure ratios? Can we be accurate? Does accuracy enhance or detract from the musical experience?

Ball calls this the “unspoken assumptions in arguments over intonation: that we can actually hear the differences.” He highlights the perception differences between musical purists and casual listeners and how what we hear is a product of our conditioning (Ball 2010 Pg76). I have wondered if our brains are constantly adjusting ET (or any tuning) to sound like what we think it should; our individual inherent tuning, whether it be pure ratios, learned frequencies or otherwise?

Duffin states that “any movement in the direction indicated will make the harmonies better” highlighting the difficulty of meeting the exact cents of an interval (Duffin 2008 Pg152). Heller also provides the differences in pitch created by each individual timbre of singers and violinists who utilise vibrato. It is the combination of these varying wave forms that create the chorus effect (Heller 2013 Pg85). This idea of combining frequencies and the chorus affect is of interest to this study as the chorus effect is a software plug-in commonly used in studio editing and features prominently in the vocals in the two albums in this study.

Many examples were found in the literature review regarding our ability to be accurate. Podnos discusses a study of string recordings that demonstrates that well known performers used approximately 40 different tunings across various tempos (Podnos 1981 Pg2). Beament provides an example of eight pianos tuned in ET by the best tuners late in the 19th century where pitches ranged from a twentieth to a tenth of a semitone out of tune (Beament 2003 Pg65).

Regardless of whether we can be accurate, there are also many techniques to disguise inaccuracies or dissonances. Helmholtz highlights how the piano is most powerful when first struck, with the beats highlighting the dissonances only after subsiding. He discusses how this influences compositions to repeat notes rather than expose the dissonances (Helmholtz 1954 Pg209). Duffin points out how vibrato was used only as an ornament when PT was in standard use, whereas nowadays, using ET vibrato is standard practice (Duffin 2008 Pg159).

Additional to the idea of disguising dissonances are the techniques to use them for aesthetical outcomes. Ball discusses the technique of pitch bending to provide emotion in music. He highlights how folk singers have been found to consistently repeat the irregularities of pitch and how Percy Grainger studied these folk singers which inspired his idea of free music where pitches became smooth glides. Another such example provided is that of Blues musicians who consistently use glides and portamento to accentuate the style (Ball 2010 Pg303).

This concept of accuracy and how it enhances or detracts from a musical performance is very much a personal experience. I recall a lecturer in my undergraduate studies saying that a rubato choice was too great for what a student should be doing. Performance
choices such as vibrato, pitch bending, selective emphasis and tuning choices will always be influenced by the experiences of the performer. As Godwin's following quote suggests, sometimes a dissonance must be embraced:

“The problematic seventh harmonic, an out-of-tune B-flat, 'shows how times are not always good, but sometimes a dissonance must be mingled in with this life'.

(Godwin 1987 Pg173)
Chapter 4 - Applications, Benefits and Implications

Throughout this research a range of applications and benefits for PT, both current and potential have been identified. This has led to a number of further avenues of enquiry which would benefit from more focussed, narrow explorations.

Key themes were uncovered and are explored in this chapter, including:

- the application of PT for musical instruments
- applications of PT music in the modern world
- emerging technologies
- conceptual considerations of applying PT
- benefits of PT
- implications of this research

The Application of PT for Musical Instruments

Through this research I have determined there are three categories of instruments that apply when considering PT:

1. Free pitch (i.e. voice, stringed instruments, trombone)
2. Fixed pitch (i.e. piano, fretted guitar, trumpet, flute)
3. Digital instruments (i.e. software, sampled and recorded)

Each category has unique considerations when applying PT. Free pitch instruments can be considered as an extension of self as there is flexibility to achieve inherent pitch as played pitch. This pitch flexibility is dependent on the willingness to experiment or de-tune against learned tuning habits. Helmholtz discusses the perfection of just intervals harmonised by voices and the modern predicament of learning to sing against equal tempered accompaniment (Helmholtz 1954 Pg207).

Fixed pitch instruments provide a greater chance of pitch accuracy in equal temperament. However, as explored throughout this study there are a number of challenges for these instruments in PT due to the Pythagorean comma and closing an octave with justly tuned fifths. There are degrees of flexibility within the fixed pitch categories such as with embouchure. These techniques enable a degree of pitch flexibility within a fixed pitch range or with tuning on open strings on a fretted guitar. Whilst a fretless guitar would provide a free pitch option, learned hand positions for chords would need to be re-learnt. Perhaps Duffin’s approach is most applicable for this category:

“Do not be afraid to be out of tune with the piano. It is the piano that is out of tune.” (Duffin 2008 Pg159)

Digital instruments can fall into both the free and fixed pitch categories depending on the specific software configurations, however, they have their own unique considerations also. These considerations also apply to instruments in the first two
categories which have been recorded and may be affected by EQ, compression and pitch editing. Whilst some digital instruments have inbuilt tuning options, such as the Sruti box application available on itunes (which have a just intonation option) others do not. An example of how not having tuning options becomes a challenge is with online music tutorials such as Yousician. These tutorials assess what is being played through the microphone on a smart device; using the application on a PT tuned piano will result in poor recognition of the melodies due to variances in pitch. I contacted Yousician to learn more about their approach to temperament but they were unable to disclose the information.

Across the available DAW’s that have a range of tuning options, there is limited consistency across applications in terms of how they operate and the terminology they use. There is also a lack of information on how scales operate within DAW’s. I found that it would have been helpful throughout the practice led component of this study for Logic Pro X to include actual frequency as well as cents under or over in the global tuning function and in the flex pitch hover over functions.

Of course, there are added complexities when performances include a combination of these instrument categories, for example instrumentalists who add-on an instrument such as a harmonica with guitar. This study finds that this blending of tuning should not be a deterrent to collaborations, rather a mindset of; anything that improves the general direction of the sound to pure intervals provides an enhanced experience.

Applications of PT Music in the Modern World

A consistent theme when researching PT is the assumption that it is only a historical tuning, as though it has been superseded, like a typewriter being replaced by a computer, the former is obsolete in the modern world. I would argue however that PT is more accessible and more beneficial now than ever. More accessible due to the technological advancements and more beneficial in the fast-paced disconnected world needing the simplicity of pure ratios. At the same time, there is a significant opportunity to utilise the benefits of PT due to the pervasiveness of music in the modern world. Music can be heard in airports, shopping centres and in personal devices which Ball refers to as “private portable soundscapes that snake ubiquitously from pocket to ear” (Ball 2010 Preface).

Two consistent themes have emerged throughout this study relating to PT in the modern world. The first relates to a lack of knowledge, understanding and cross pollination of intelligence regarding frequency research developments. The second theme relates to the rate of progress and inability to predict the future. This was apparent watching the Australian music documentary Blood and Sweat showing that in the 1960’s, the biggest selling items were the harmonica and a harmonica song book at Alberts Music in Australia. This demonstrated how quickly and how drastically the music scape changes and how could we possibly predict what’s next?

The two themes are linked and with such a lack of knowledge, the progress and development of PT will largely be inhibited. Furthermore, without education, how would the developments be in the best interests of the modern world?
The lack of knowledge is evidenced by the frequent use of incorrect terminology. Throughout this research it has commonly been experienced that software applications use the word tuning when they mean scale or key. The lack of understanding between hertz and cents is another example. There are many examples in popular culture that refer to the power of frequencies but lacks substance. The 2012 film Ghost Maker is an example of this where they make references to the diminished 5th banned as the devil’s music and the frequency of 7hz being death inducing. These notions are inspired by how powerful frequencies can be, but we lack the knowledge to know definitively which frequencies have which effects.

The lack of knowledge is exacerbated by a lack of accessibility and information. The majority of software applications for frequency analysis require in-depth computer knowledge to simply install them, let alone make use of them. I became aware of this when trying to install the common program, Scala, where you need to install and run layers of developer codes and widgets to successfully run the application.

A lack of knowledge could be addressed by more and consistent information. One way this could be addressed is through creative works being supplemented with written content. It was evident whilst reviewing the historical literature that in the Baroque, Classical and Renaissance periods composers would often supplement their compositions with a dialogue or instruction on temperament or individual markings of intonation for specific notes or instruments. The modern equivalent might be producers of mainstream contemporary music supporting their track with a dialogue of technology utilised such as synthesisers, plug-ins and effect generators. However, as I experienced with one of the producers collaborating in the research; this information is seen as intellectual property that needs to be protected and not shared.

Other information that would be beneficial to minimise the lack of knowledge could be an online database that summarises and maintains up to date information on each of the DAWs PT (and broader tuning) abilities and how to access and apply settings. Again, when contacting companies (such as Logic and Yamaha) for information relating to their tuning settings, I would either receive no response or a response advising that they couldn’t disclose the information. My conclusion was that in all likelihood this technical information wasn’t readily available or understood, even within the companies that develop the technologies.

The second theme for the modern world, the rate of progress, is complex as music is informed by and influences so many aspects of our modern lives. Artistic, social, scientific and technological aspects of life are all progressing at different rates with musical applications merging across these areas. The developments are often only limited by our imaginations. Davies refers to a potential development that covers across each of these areas as a hologram orchestra that can operate as a backing to play along with (Davies 2003 Pg101).

Not only are there new technological developments, but there are ways to enhance existing art forms. There is an opportunity in film score compositions to use tuning systems to create mood or experiences for listeners that aren’t currently available using only ET. This similarly applies in the broader community when we consider how sound and music is being used at train stations to create social outcomes. Schafer discusses
noise pollution where the mitigation response is noise abatement, however highlights that this is a negative approach. He asks rather, that we consider the sounds that should be preserved, encouraged and multiplied (Schafer 1977 Pg3). In regard to this study, this idea applies equally to which frequencies we desire to be enhanced in our social spaces. Again, here we have an example of how enhanced knowledge would provide us with the information required to apply PT in the modern world.

Emerging Technologies

In the modern world, emerging technologies are the norm. In parallel to sound developments, we are seeing visual resolution continually being enhanced with 3D, pixel counts, 360-degree film, virtual reality and holographic technologies. Whilst sound developments are equally progressing, they are perhaps not as widely understood. Throughout this study I discovered emerging technologies such as the Nura headphones and the Muzo device. These technologies prompted the questions of what would be the experience of PT in these devices? And, are these devices being developed with consideration of PT and other non-standard temperaments?

Both the Nura headphones and the Muzo device have been funded by crowd funding. The Nura headphones received over $100,000 in under a few hours and the Muzo device successfully funded over half a million dollars in 2016. This demonstrates the social support for devices that enhance the sound experience. The headphones automatically respond to your auditory experience with soundwave technology that measures your hearing and brain response in 30 seconds and adapts the sound quality. The Muzo device creates a sound cave by neutralizing sound waves. It has a serenity mode that uses anti vibration technology, a sleep mode and a secret mode that is created by sound masking.

I explored new technologies as part of the practice led activities in this study, notably, listening to mixes through two Bluetooth sound devices, one at the low end of the sound spectrum (Philips nfc portable speaker) and one at the high end (Jabra earphones). The portable speaker provided a representation of the current trend in speakers to be cheap and compact, there are a plethora on the market, and whilst the Phillips device was not the smallest and cheapest it clearly compressed the sound and impacted on the enhanced qualities of music recorded in PT. The Jabra ear phones however provided a sound experience that was more balanced, and somehow some of the discrepancies in PT seemed to be somewhat evened out. When listening to Beyond Belief, I found the sound to be far more transparent through the headset. I felt as though there was more of my personality evident through the vocals with the Acapella section particularly haunting. I felt more drawn into the sound as if I am in a virtual reality version of the sound. I could see visually where the sounds are placed in the mix, far more than with the studio monitors or any other speakers. I described this in my diary entry as follows:

“It was almost as though I am in a space where I can place the sounds around me and reach them with my hands.” (Jensen 2012 – 2017 DE323)
Conceptual Considerations of Applying PT

This study prompted a range of conceptual considerations. One idea is the reflection that tuning can be considered as either standard or complex. Standard tuning experiences would be ET as it is easily understood, easy to apply, and provides a regular, standard experience for both creators and audiences. Just, Pythagorean, or other systems based on pure ratios could be considered as complex due to their difficulty in comprehension, challenges in their application requiring workarounds and a depth of human experience that requires a methodology of sorts to be fully experienced.

If there were to be a standard and complex delineation of tuning systems, there would likely need to be some form of confirmation that what was being consumed was in fact what it was marketed as. A comparison can be made here to organic foods, where the consumer has to trust the label, as often it is difficult to discern organic produce from sight and taste alone. Similarly, it can be difficult to discern pure ratios from sound and experience alone, and therefore a system such as Certified Organic could be applied as Certified Pure Intonation or Certified Pythagorean. It is not far beyond the technological possibilities for this to be an automated process, considering the likes of Spotify where a snippet of a recording can be run through an algorithm to find the song title and artist.

Another conceptual consideration throughout this study has been the relevance of traditional music notation when working with non-standard tuning systems. This consideration was prompted by two things; firstly, the historical anecdotes of temperament markings on manuscripts and secondly how many new technologies are moving away from traditional notation altogether. Particularly, where there is a training component, or in the gaming arena such as Sing Star and Guitar Hero new ways of representing notes are emerging. This prompted the question; would a new notational device that focussed on frequencies or pure ratios provide a different musical experience?

The most notable conceptual consideration however is the idea of the closed and infinite octave. In his Blog; Harmonic Frequencies & 432 Hz Research\textsuperscript{15}, Schotsborg discusses the spiralling nature of the universe and does not see it as a closed circle. He provides how the Pythagorean comma makes music infinite and cosmic, not as a mistake to be fixed. Similarly, Duffin refers to the infinite nature of the harmonic series, creating overtones well beyond human hearing (Duffin 2008 Pg22). These concepts, together with the lived phenomenology of this research have led to a realisation that both the closed octave and the infinite octave may be required. The infinite octave has a purpose of connection; to self, to vibrations, to desired experiences. The closed octave has a purpose of grounding for technicality, reliability and stability. This idea of the closed and infinite octave aligns well with the concept of standard and complex tuning selections.

\textsuperscript{15} http://blog.qualiaplus.com/2013/04/harmonic-frequencies-432-hz-research.html
Benefits of PT

Music is known to have a number of benefits, it can provide togetherness and unity, it can even encourage productivity as we have seen with work songs. It can provide emotional release and motivate physical responses such as dancing. The question this research explores asks whether these existing benefits are enhanced by PT and/or whether there are further benefits. One of the challenges in this research has been unravelling the statement that music is healing and an assumption that PT could be healing. The statement prompts an exploration on the concept of healing. Ironically, to heal is defined as to make sound or healthy again. Definitions of sound focus on its vibrational nature so arguably the statement music is healing could be more accurately replaced with music provides vibrational alignment.

In his paper *Music and MP3s Missing Harmonics*, Curtis provides an excerpt from author Itzhak Bentov regarding how frequencies circulate through our bodies to maintain our health. He describes how an out of tune body results in illness, essentially when the periodicity of one organ or part of our body loses its alignment to other systems in the body, disease occurs. He also refers to this ability to create healing through using sound to realign the frequencies in the body ([Curtis 2008 Pg3](#)). Ball also discusses wellness through sound with regards to neuroscience findings that suggest that the brain prefers combinations of frequencies in simple ratios. However, he also provides that there is much yet to be learnt in this field ([Ball 2010 Pg175](#)).

Whilst there are many benefits of working with PT that could potentially be realised, the most significant benefit uncovered through this research can be applied right now. This is the ability for PT, and/or other complex tuning options to provide a way of self-assessing your alignment to the frequencies. Additionally, PT provides the ability to use music to assimilate to the frequencies and achieve a desired vibrational alignment.

In my diary notes I articulated this phenomenon:

> “PT has become a guide for my wellbeing. I can benchmark my sense of self against it, there are noticeable differences; when playing after a healing, or a busy day at work, or feeling unwell or unbalanced or playing in consecutive sessions or after having a break from practice, there is a different experience of PT in each of these scenarios. I believe that I would be otherwise unaware of these differences in my sense of self without the subtleties of harmonies when playing in ET. PT is a benchmark for physical harmony.” ([Jensen 2012 - 2017 DE198](#))

This use of PT music could have broader applications, for example, the spoken word findings in the creative work suggest that it may be beneficial for PT music to accompany spoken recordings and live speeches. Such application may be beneficial in accompanying meditation recordings or assisting a speaker who may have nerves or requires support in achieving the desired mood for a presentation. Ryan discusses this as a concept of intent, highlighting the difference between choosing to emit your own frequencies rather than absorbing those around you ([Ryan 2014 Pg68](#)). Using PT music is a way of choosing how you want to resonate and what you are aligning to and emitting through your actions and being.
Implications of this Research

Whilst this research has provided an understanding of the practical and lived experience of working with PT, it’s most profound finding has been how to leverage the tuning as a benefit. Through this research I have built an understanding of how PT music can become a mechanism for adjusting the physical and emotional states for those that are willing to participate in the experience it creates.

Early in the research activities there was a strong awareness of the physical impact of the frequencies resonating. After the physical responses normalised I became more aware of the emotional states that are enabled by the space that these resonant frequencies create.

This finding is a subtle yet significant shift in perception on the benefits of working with frequencies that are aligned to pure ratios. When reading a range of comments posted on the tone generator website\(^\text{16}\) it was evident that people are looking outside of themselves for frequencies to change their state of being. The findings of this research suggest that the frequencies provide a guidebook of sorts that enable an individual to identify what is occurring within themselves and, if desired, to consciously and proactively align themselves to the resonances.

Key questions that can be asked to trigger this include; what is the music telling you about yourself? Are you aligned to the music? Are you in tune with the music? Are you in tune with yourself? The difference in this line of questioning is the shift in focus; it is not about whether the music is in tune, it is about whether you are. This line of phenomenological enquiry can be summarised as inside out, not outside in. The music isn’t outside of you, it permeates your being with its vibrations almost as instantly as they are created, therefore the consumption of the frequencies is occurring from within - they are experienced rather than heard, they are felt rather than logically assessed.

Whilst this resonant nature is true for all music regardless of temperament, there is a difference in the ability for PT (or pure ratio tuning) to create a space that doesn’t function the same with ET. When you sit at the piano to play music in ET, you know what to expect, the tuning is clinical and predictable, you are already aligned to it, your body responds as it always has and your emotional state is not challenged by it. When you sit at the piano to play music in PT, there is more space within the experience. This space allows room for the vibrations to settle in new ways within your physicality. Your emotional self is also opened up to new reflections. The space that is created by PT resonances enables out-of-the-box thinking, removing limitations that can be caused by the predictability of ET.

This awareness of how PT can be used to provide a different experience for creators and listeners, suggests that there are some conditions for the way in which PT should be approached. These conditions form a methodology for the enhanced experiences that can be gained from working with pure ratios in music:

\(^{16}\) http://onlinetonegenerator.com
**Intention:** your conscious aim to be aware of different aspects of your experience such as; how you perform, awareness of your physicality, mood, emotion, connection with audience.

**Openness:** your ability to be open to the experience without preconceived notions of what should be heard or felt.

**Duration:** a commitment to see the experience through various durations, either in a single sitting or over prolonged periods of time.

**Environment:** selecting an environment that is supportive of the experience and/or using technologies that enhance the sound and vibrational experience.

**Outcome:** being present to what has been experienced and exploring whether or not the tuning has affected a changed state.

How this methodology for experiencing PT could be practically applied:

1. Decide to experience PT, and be open to exploring different styles, instruments and settings without an anticipated outcome in mind.
2. Allow yourself time to consider how the frequencies are making you feel.
3. Consider how you would describe the PT music; is it alive, resonant, connected, vibrant, complete, grounded?
4. Consider whether or not you are aligned to the music and the characteristics you have heard within the music. Do the frequencies flow through you or do you resist them? Where in your physicality do you resist it? Why are you mentally or emotionally blocking its resonance?
5. If you are blocking the experience in any way, commit to a longer duration or repetition of the music and open yourself to the vibrations. You may adjust your environment to do so, such as changing from a speaker to headphones.
6. Observe whether, and how, your physical and/or emotional self may have been changed by the experience. (If there has been no change, review your approach to the previous conditions, i.e. are you genuinely open to the experience? Have you committed to a long enough duration?)

In summary, if music in PT provides a richness in its experience, then this richness becomes a benchmark for how you want to feel. It can also then provide you with an awareness of how you are feeling compared to the benchmark. By repeatedly immersing yourself in this richness of experience and allowing yourself to be open to the effects of the experience you can be transformed from how you are feeling, towards how you would like to be feeling. This phenomenon can be exacerbated by selecting styles of music that also encourage particular moods, i.e. dance music if you want to be energised.

After working with PT music for six years throughout this research I have integrated this methodology into not only all of my creative pursuits but it has permeated other aspects of my life where I have desired a change in state. I came to the realisation towards the end of these six years that playing music isn't as satisfying if it doesn't change your state. If you are already feeling relaxed, and you play music that is relaxing
it is not as satisfying as say feeling relaxed, and experiencing music in a way that
creates a space to be contemplative. The examples of how PT music can create a space
for individuals to have a change in state are innumerable.

Further Avenues of Enquiry

A wide range of recommended research has resulted through the findings of this study.
The themes cover early education, having a consolidated knowledge base, exploration
of environments, focussing on different audience groups, a number of narrow
quantitative studies and ongoing focus on technological developments. This section
details the further avenues of enquiry identified throughout the study and provides
recommended research for future researchers in this field.

Early Education

As this study uncovered a theme of conditioning towards ET, I was prompted to
consider early education in schools and a possible change in approach. Reimer and
Wright refer to Cage’s comments regarding schools continuing to focus on historical
approaches to music, particularly considering the range of technology available to
encourage creativity (Reimer and Wright, 48). This study therefore recommends an
eyth early education approach that focuses on the physics of sound as a precursor and
introduction to music. This approach would potentially encourage a wider range of
creativity and a method that focuses on the experience of sound and music. It would be
of interest to this study to learn if students taught in this way have a greater appreciation
of and understanding of pure ratios and their benefits in music.

Knowledge Base

It has become apparent through this study the number of incomplete sources,
misinformation and lack of cross referencing across disciplines regarding the
experience, applications and benefits of particular frequencies. It is recommended that
comprehensive research be undertaken to create a consistent knowledge base bringing
together specialists across areas such as mathematics and physics, together with medical
practitioners, inventers, psychologists and musicians. For example, musicians may
prefer a particular key, that psychology suggests holds a particular mood, that medical
studies show is the resonant frequency of a particular organ in the body and physics
shows the environmental conditions to enhance the resonance of that particular
frequency. Much of this information already exists although it is fragmented across the
disciplines.

Another valuable knowledge base to support the application of PT is the capabilities of
the various DAWs available for the creation of live and recorded music. Added to this
topic is the rate of change within software resulting in the knowledge quickly becoming
obsolete as some updates are as often as weekly. A matrix of which applications hold
which scales and which capabilities would be a beneficial industry resource.

The third knowledge base that would be beneficial to support the application of PT is a
database of technology devices that support the use of PT. Mainly, this area of enquiry
is to discover whether new technologies such as speakers, headphones, sound chambers and visual sound technologies have been developed with alternative tuning experiences in mind. This knowledge base could contain what settings may have been included to enhance the experience and what those experiences are.

Environments

Further avenues could be explored regarding PT and acoustical engineering to discover the best ways of enhancing the PT experience. A starting point for this area of enquiry could be exploring PT in an anechoic chamber to determine whether the PT experience is enhanced or diminished with a focus of the prevalence of upper partials in this environment. Other more complex environments could be explored after this baseline has been created with a focus of the experience in social settings such as stadiums, shopping centres, office spaces and classrooms. This study could be a precursor to supporting remediation for noise pollution.

It is also recommended that studies similar to this one are pursued to cross reference the experiences captured. Capturing live performances of PT in different environments would be an interesting further study.

Audience Analysis

This research focussed on the experience of PT without segregating audience groups. Further studies that segregate particular audience groups are recommended that focus on psychoacoustics. Recommended studies include:

• Explore experience of PT for individuals with impaired hearing to explore vibrational awareness of the frequencies compared to equal tempered vibrational awareness.

• Explore the experience of PT for people with perfect pitch. Focus especially on durations, for instance: how long does it take to break down entrained tuning for this audience group compared to those without perfect pitch. Consider whether there is a third group with relative pitch capabilities.

• Explore remote communities experience of harmony that is built on pure ratios. This could be done by sourcing and analysing tribal recordings for inherent pitch.

• Explore in depth the tuning preferences of unaccompanied vocal groups with a focus on inherent tuning, prevalence of pure ratios and a comparison of solo vocalists to group singing tuning.

• Explore where in the human body different frequencies are experienced physically. This could be done by playing to a group of blindfolded individuals who physically indicate where in their bodies particular frequencies or sections of music are felt resonating.
• Explore whether certain personality types have preferred instrument choices. Particularly whether there is alignment to free pitch instruments for relaxed and flexible personality types and fixed pitch instruments for more rigid and structured personality types.

Quantitative Studies

Due to the nature of this study, predominantly qualitative information was gathered, primarily through the diary entry approach. This information has led to the recommendation for a number of studies that are more quantitative in nature. One study could be an exploration of the experience of two identical (preferably new) pianos one tuned to ET and one to PT. This study could identify whether there is a different sensation in the fingers of pianists. The study could also be extended to full body awareness of the resonant vibrations and should be undertaken both with sound and without by blocking their hearing.

Another recommended quantitative study is with string players where it would be of interest to explore their inherent tuning of the open strings as perfect 5ths in pure ratios. It is advised to focus on the A frequency as well as the ratios between the strings. It is also advisable to test this after being immersed in both PT and ET for set periods of time.

A study on enharmonic pitch is also recommended for further analysis to uncover the prevalence of accentuating flats and sharps in different keys, moods, styles and temperament.

A study on ear fatigue is also an area of further enquiry to quantify whether there is a reduction in the sensation in either duration or intensity when producing music that is comprised of pure ratios.

A range of quantitative studies are recommended to further explore the experience of existing and emerging technologies, these would include the experience of PT:

• through different formats such as mp3s, records, and sound formats
• through varying degrees of compression and other plugins
• when different EQ settings are used to minimise, or enhance frequency spectrums
• when using synthesised instruments compared with sampled instruments
• regarding overtone patterns on real versus synthesised instruments.

Other studies already highlighted throughout this paper include:

• exploring the same song being performed in the two tuning systems
• exploring being immersed in PT for different periods of time
• exploring PT through more diverse arrangements and instrumentation.
• a study on the wave forms of singers in ET and PT
• looking at the alignment of visual and sound (JND) perception
Conclusion

This research has found that the experience of PT offers a different quality of experience to ET. It has also found that this field is under explored, primarily because there is no orthodoxy for creating in a manner that is mindful of temperament selection. The new knowledge arising in this study relates to the experience of PT and the practical methods for creating works in this system. This new knowledge primarily highlights the requirement for a willingness to participate in the experience and to expand our focus from hearing to experiencing. In the cognitive science of music, where studies that are more experiential in nature have been undertaken, they have done so using ET. With this in mind there is a rich potential field waiting to be explored.

This research has found that composers, inventors and theorists have continually explored new temperaments rather than developing consistent conventions for exploring the experiential elements of the systems that have already been established. The lack of orthodoxy for the composition and production of music limits the ability for depth of understanding in this area. The diversity of experiences captured by the collaborators in this study is testament to this challenge. It is an overarching recommendation from this research that we require a collective exploration of the core systems, thoroughly, with a standard approach of enquiry.

In closing, this research has overwhelmingly been beneficial on a personal level. It has awakened a richer understanding of self in performance and artistry, it has enabled the development of new ways of thinking around presence and awareness of self and enabled the development of new thinking models. Due to the experiences and findings over 6 years working with PT; I will personally continue to practice, compose, perform and explore the creation of music in PT.
Glossary

**Experiential**: involving or based on experience and observation.\(^{17}\)

**Holistic**: characterized by comprehension of the parts of something as intimately interconnected and explicable only by reference to the whole.\(^{18}\)

**Horogram**: a visual representation to algorithmically generate long rhythmic and scalar patterns using the Golden Ratio (\(\Phi\)).\(^{19}\)

**Inherent**: existing in something as a permanent, essential, or characteristic attribute.\(^{20}\)

**Just Intonation**: any system of tuning in which all of the intervals can be represented by whole-number frequency ratios, with a strongly implied preference for the simplest ratios compatible with a given musical purpose.\(^{21}\)

**Overtones**: a musical tone that is a part of the harmonic series above a fundamental note and may be heard with it.\(^{22}\)

**Pythagorean comma**: an interval of 23.46 cents, being the difference between twelve 5ths and seven octaves.\(^{23}\)

**Soul**: the spiritual or immaterial part of a human being or animal, regarded as immortal.\(^{24}\)

**Wolf notes**: a harsh or out-of-tune effect produced when playing particular notes or intervals on a musical instrument, caused either by the instrument’s construction or by divergence from equal temperament.\(^{25}\)

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18 ibid
23 http://www.oxfordmusiconline.com/grovemusic/search?q=Pythagorean+comma&searchBtw=Search&isQuickSearch=true
25 ibid
Bibliography
(Contains cited references only and not all materials reviewed as part of research)


Parnicutt, R. *Pitches at missing fundamentals in musical chords: Are they really perceived?* Australian Music & Psychology Society (AMPS) monthly seminar series, Melbourne, Australia.


Extended Bibliography


Iamblichus and T. Taylor (1986). Iamblichus' Life of Pythagoras, or, Pythagoric life : accompanied by Fragments of the ethical writings of certain Pythagoreans in the Doric dialect and a collection of Pythagoric sentences from Stobaeus and others. Rochester, Vt., Inner Traditions International.


Rowe, N. and Pythagoras (1740). The golden verses of Pythagoras Translated from the Greek, by Nicholas Rowe, Esq. [Edinburgh], [s.n.]: 12p.


Profiles the life and work of Pythagoras, who has been immortalised by a single mathematical theorem but was also a great mathematician, philosopher and political leader.


Parncutt, R. *Pitches at missing fundamentals in musical chords: Are they really perceived?* Australian Music & Psychology Society (AMPS) monthly seminar series, Melbourne, Australia.

Creative Works

Original Album

Provided separately via download link

Re-imagined Christmas Carols

Provided separately via download link
# Appendix

## Original Album List

<table>
<thead>
<tr>
<th>Track #</th>
<th>Song Title</th>
<th>Composed By</th>
<th>Produced By</th>
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<td>A New Day</td>
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<td>A Love that you Own</td>
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<td>Taner Remzi</td>
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