Do Androids Dream of Computer Music?

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DO ANDROIDS DREAM OF COMPUTER MUSIC? COMPUTER MUSIC IN THE AGE OF MACHINE ANXIETY

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Australasian Computer Music Conference 2017

PREFACE

I like to think (and
the sooner the better!)
of a cybernetic meadow
where mammals and computers
live together in mutually
programming harmony
like pure water
touching clear sky.

Richard Brautigan, *All Watched Over by Machines of Loving Grace* (1968)

This rehearsal will end, the performance will end, the singers will die, eventually the last score of the music will be destroyed in one way or another; finally the name "Mozart" will vanish, the dust will have won. If not on this planet then another.

Philip K. Dick, *Do Androids Dream of Electric Sheep?* (1968)

What kind of future do we want? A more pertinent question may be: do we have a choice? Will we be strolling through cybernetic meadows, free of our labours, watched over by machines of loving grace? Or perhaps it will it be a dystopian future of the kind Philip K. Dick describes in his novel *Do Androids Dream of Electric Sheep?*(memorably reimagined in Ridley Scott's film *Blade Runner*.) Artificial Intelligence and robotics are receiving a lot of media attention, but optimism about a machine-enabled Utopian future appears to be giving way - not for the first time in human history - to machine-induced anxiety. Humans create tools; but then the tools change us. This has been the case since the very beginning of human history. In this time of rapid development of radically new tools of unprecedented power, one must consider that the very definition of 'life' may be changing. If that is the case, then we urgently need to understand this change in order to come to terms with the technology that we have created.

The central character in Philip Dick's novel is a bounty hunter who chases and 'retires' escaped androids. It's significant that one of his targets is a female android opera singer. If human life is to be fundamentally changed by technology, we must wonder what will happen to music. If music is a reflection of life - a mirror of who we are – then music must change as we change. That is the underlying theme of this conference and the concerts that are part of it.

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USING THE TEXT OF FINNEGAN'S WAKE TO CREATE THE ELECTRO-ACOUSTIC WORK HUSH! CAUTION! ECHOLAND!

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ABSTRACT

Hush! Caution! Echoland! is part of a series of works entitled "Sounding Finnegan's Wake". Here computer/algorithmically generated instrumental, acousmatic, interactive, and audio/visual pieces are being developed, based on the sound and structure of Finnegan's Wake. The premise informing these works is that Finnegan's Wake can be understood as a textual work and as sound art. In Joyce's writing these two approaches are complementary, each informing and influencing each other.

Hush! Caution! Echoland! takes chapter one of Finnegan's Wake as its material, from which to create a score for traditional instruments and electronics, derived from the structure of the text as expressed initially through its ASCII representation. This is deconstructed through a number of processes to form the score for Flute, Clarinet, Violin, Viola and Cello. The electronic part also uses the ASCII representation of the text and spatializes the instrument sounds according to that structure. This is done through use of synthetic reverberation and panning techniques.

Processes for using text to generate music have been explored by many, including the author, and the outcomes are varied. These are discussed in the accompanying submission of the related creative work.

INTRODUCTION

This paper will discuss the processes used to generate Hush! Caution! Echoland!; its focus is on the developing of this work, with a brief discussion on precedents to it and its process.

Hush! Caution! Echoland! is part of a series of works entitled "Sounding Finnegan's Wake". In this series computer/algorithmically generated instrumental, acousmatic, interactive, and audio/visual pieces are being developed, based on the sound and structure of Finnegan's Wake. The premise informing these works is that Finnegan's Wake can be understood as a textual work and as sound art. In Joyce's writing these two approaches are complementary, each informing and influencing each other.

This part of "Sounding Finnegan's Wake" takes chapter one of Finnegan's Wake as its material, from which to create a score for traditional instruments and electronics of Hush! Caution! Echoland! The instrumental part is derived from the structure of the text as expressed initially through its ASCII representation. This is then deconstructed through a number of processes to form the score for Flute, Clarinet, Violin, Viola and Cello. The electronic part also uses the ASCII representation of the text and spatializes the instrument sounds according to that structure. This is done through use of synthetic reverberation and panning techniques.

Processes for using text to generate music have been explored by many, including the author, and the outcomes are varied. These processes range through an aesthetics based text setting, such as the writing of a pop song or liturgical music where the compose a response to what they they think complements the text or and answers the intentions of the author. Other approaches, such as using the inherent sounds of the text are comparatively rarer. Brunson's (Brunson 2009) discussion of processes is comprehensive, and Eberhard Blum's (Cage, Blum, and Cunningham 1991) renditions of Cage's Mesostics re Merce Cunningham and Amanda Stewart and Chris Mann's (Jones 2016) works are indicators of taking text from the descriptive realm to the less descriptive realm of sound art are examples. Processes for using text as a system for musical creation that is not designed to represent the meaning of the text are even rarer, the author has explored this (Alsop 1999, 2007, 2011, 2013, 2014), and this project is a continuation of these explorations. Work by others in the area is varied across a wide field ranging through exemplars and processes (Hammond and Reiner 2006, Manaris and Brown 2015, Kirke and Miranda 2017, Parson 2010, Rangarajan 2015, Harmon 2017, Laurie 2005).

There are also the less formal discussions and activities regarding Finnegans Wake and choices work in general, these include: Waywords and Meansigns (Pyle and Kipperman 2017), and From Swerve of Shore to Bend of Bay (Chrisp 2017). These contributions add significantly to the thinking and practice regarding Joyce and his works; it is their informality which creates a certain freedom that is not always available within the more academic contexts.

ASCII TO SCORE

While ASCII in itself is not a representation of word sounds, what it can do is indicate the relational structure of letters within a document, and these letters can represent, at a most basic level, word sounds. As this part of the Sounding Finnegans Wake Project is concerned with the structural underpinnings of Joyce's text, the use of the ASCII values of each letter of the text presents an abstract process from which it is possible to develop a musical work.

The composition is loosely based on the following system, where 10 consecutive ASCII numbers create a single sonic event, the process is outlined below:

ASCII # 1 = pitch class
ASCII # 2 = register
ASCII # 3 = amplitude (dynamic ppp to fff)
ASCII # 4 = duration
ASCII # 5 = inter-onset time
ASCII # 6 = Instrument
ASCII # 7 = articulation
ASCII # 8 = virtual space (reverberation)
ASCII # 9 = actual space (panning)
ASCII # 10 = transition time

This process then repeats until all ASCII numbers, 12521 in total, in chapter one are used. This process doesn't consider whether the ASCII numbers are referring to actual letters, spaces, or punctuation marks. While the punctuation marks are not necessarily related to word sounds, they do indicate potential inflections or intonation characteristics, and the temporal aspects Joyce intended to imbue his work with.

Here, after a sequence of 10 ASCII numbers are iterated from the text, a new note is generated. Each note is then parsed by the composer to ensure fit with the chosen instrument. This system will be used to create a musical score for performance and instructions to the musician operating the electronics.

The number sequence to generate the first note is: 32 114 105 118 101 114 114 117 110 44. This then generates the outcome 56 48 30 1305 135 4 2 1583 6 356.

In this case the musical output can be seen in the A flat note played by the violin in measure one in **Figure 1**

ASCII # 1	32 (space)	pitch class	8
ASCII # 2	114 (r)	register	48
ASCII # 3	105 (i)	amplitude	30
ASCII # 4	118 (v)	Duration (msecs)	1305
ASCII # 5	101 (e)	inter-onset time (msece)	135
ASCII # 6	114 (r)	instrument	4
ASCII # 7	114 (r)	articulation	2
ASCII # 8	117 (u)	virtual space (reverberation)	1583
ASCII # 9	110 (n)	virtual space(panning)	6
ASCII # 10	44 (,)	transition time	356

Table 1. Conversion of 10 ASCII numbers to a note event

It should be noted that the resulting note value of 56 is addition of the original pitch class of 8 and the register value of 48.

Table 2 shows the selection of articulation choices made for this piece and **Table 3** shows the selection of dynamic ranges chosen. These choices are completely arbitrary and at the discretion of the composer with consideration of the capacity of each instrument.

	0	1	2	3
Flute	Trill (#)	Trill (b)	Vibrato	Flutter tongue
Clarinet	Trill (#)	Trill (b)	Vibrato	Flutter tongue
Violin	Trill (#)	Trill (b)	Battuto	Col Legno
Viola	Trill (#)	Trill (b)	Battuto	Col Legno
Cello	Trill (#)	Trill (b)	Battuto	Col Legno

Table 2. Variations in articulation.

MIDI velocity	Dynamic marking
0 – 15	ppp
15 – 30	pp
30 – 45	p
45 - 60	mp
65 – 80	mf
80 – 95	f
95 – 110	ff
110 - 127	fff

Table 3. Dynamic ranges.

A simplified version of the Max patch used to create this piece is shown in figures 1 and 2 below. **Figure 1** shows the pitch class, register, dynamic, duration, and inter-onset times for the note discussed earlier. After the designation of each column the top row shows the ASCII number, the second to fourth rows show the operations done on that number, and the final row shows the outcome that is then used to produce a note event.

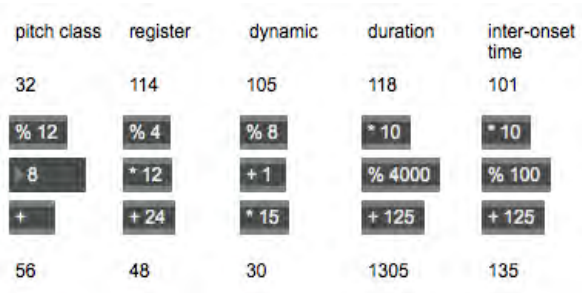

Figure 1. creating a note event from ASCI numbers

To explain in greater detail: in column 1, which ascertains the note to be played, ASCII number 32, is fed through a modulo of 12, resulting in the number eight. This number is then added to the register value, which is ascertain in column two. Here the ASCII number is 114, which is being fed through modulo of four, as four possible register values are available, and the output is multiplied by 12 with a further edition of 24 to ensure that the last possible pitch is MIDI note C1. In this case their ASCII number is 114, which when put through a modulo of 4 results in two, which is then multiplied by 12 to create 24 after which 24 is added.

Similar processes are used to define the dynamic, duration, and inter-onset value, shown in **Figure 2**. Again it should be noted that the numbers chosen for the operations are done at the discretion of the composer.

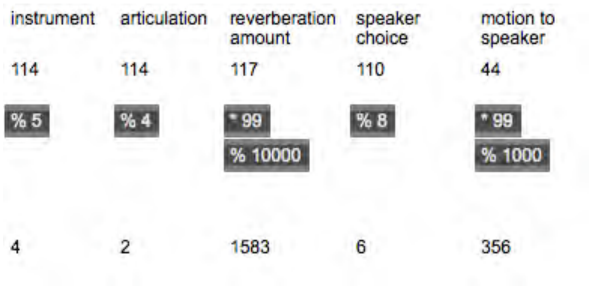

Figure 2. Defining instrument, articulation and electronic broadcast parameters.

Here the choice of instrument, in this case instrument 4, which was decided to be the violin. A modulo of five was used as 5 instruments were chosen, and an articulation 2, which case of the violin relates to using battuto, as shown in **Table 2.**

The reverberation amount is considered as the duration of the reverb tail in milliseconds, the speaker choice defines which speaker the amplifier to Sound of the specific instrument is to be played through, and the motion to speaker refers to the period of time taken for that specific instrument to move from the speaker and it was previously broadcast three to the current speaker.

DEVELOPING THE SCORE (INTERPRETING THE GENERATED DATA)

The score shown in figure 1 below is drafted in Logic Pro 10 from MIDI generated by Max patch used to create Hush! Caution! Echoland! This data has been quantised within 16th note triplets for performance, therefore the ordering of the notes on the page does not directly represent the ordering of notes as generated from the Max patch. In some cases the temporal positions of the notes as generated by the Max patch were in differences of milliseconds, and it was considered unlikely that the the audience would be able to hear these differences, musicians would be able to play the notes at such accuracy, or that the differences were vital to the musical ideas and expression. An example of this and be seen in the inter onset time of 135 milliseconds allocated to the first note as shown **Table 1.** Here it was considered that the real life interaction between musicians and the notes that they are playing would not show that particular duration.

This is considered appropriate, as any reading of a text is a sonic interpretation of it by the reader, just as any reading of score is a sonic interpretation of it by the musician. Other arbitrary decisions were made when generating the score. Occasionally note events that had very long durations were truncated, and pitches were either lowered or raised in order to fit within the range of chosen instrument; these choices were done at the composer's discretion.

As can be seen its note has a specific dynamic and specific articulation. These are designed as indicators to the performer, to be considered more as suggestions of way in which the note should be played. This approach harks to the way in which a script may be performed by an actor, where each individual actor is expected to bring their own interpretation of how the text should be spoken in performance.

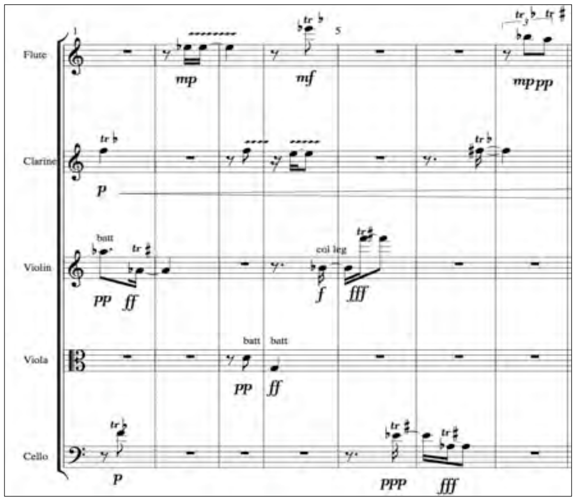

Figure 3. Example of the score to Hush! Caution! Echoland

CONCLUSION

This paper is a brief discussion of the processes used to develop a version of Finnegans Wake for acoustic instruments and virtual and actual space. It is part of a developing range of works that explore the possible sonic interpretations of this text. The process avoids traditional ideas of text setting, such as John Cage's "The Wonderful Widow of Eighteen Springs", or interpretive works such as Takemitsu's "riverrun". A comprehensive listing of musical settings and interpretations of Joyce's works is offered by Derek Pyle (2017). at Waywords and Meansigns.

The processes used in developing Hush! Caution! Echoland! will be developed in future works based on Finnegans Wake, in particular to develop works for solo instruments and voice.

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DECEPTIVE SOUNDS: AUDITORY ILLUSIONS & ARTEFACTS IN SOUND ART

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School of Engineering	School of Music

ABSTRACT

There is a rich history in the visual arts of works which use optical illusions that confuse and excite the eye. In Sound Art, there hasn't been established movements which have focused on auditory illusions. However, there are a range of works which share similar experiential themes. This paper examines the artefacts and oddities of our aural sense, and catalogues how these interesting perceptual phenomena have been explored in sound art. This cataloguing will connect the implicit experiential and perceptual themes that are at force in a range of works, and will speculate on underexplored fields for sonic exploration. To this purpose, two new sound works by the author, *Destructive Passages One & Two* and *rise.risset*, are discussed.

1. INTRODUCTION

Optical illusions have been a source for many artistic works and movements. The realism of the Trompe-l'œil movement, the impossible forms of M.C. Esher, and the paradoxical movement in the static images of the Op Art practitioners all offer interesting new perceptual confusions. Through confusing and tricking the senses, they invite the audience to meditate on their perceptual apparatus. In experience of these works, we can become aware of the subjectivity and deficiencies of our perceptual apparatus, and its constant mediation of our world.

The eye and the ear have their own distinct artefacts and oddities, which can be explored though different forms of illusions. In sound art, there hasn't been established movements which have focused on auditory illusions. However, there are a range of works which share similar experiential themes. This paper examines the different artefacts and oddities between our visual and aural senses, and catalogues how these have been explored in sound art.

The field is organized into different forms of effects. Impossible Sounds collect two auditory illusions that are perceived to have perpetual motion: Shepard tones and Risset rhythms. They share commonalities with works by M. C. Esher and other artists, who used impossible objects in their works. The next category is a large collection of non-linear perceptual effects. These are experiences where the auditory system adds distortions and artefacts to our experience. Lastly, the Phantom Sources section covers a range of spatialisation techniques which have a rich history in electroacoustic music.

Through organising the modes of perception framing that artists have employed in their works, some of the differences between our visual and aural senses will be teased out. This cataloguing will connect the implicit experiential and perceptual themes that are at force in a range of works across multiple mediums, and will speculate on underexplored fields for sonic exploration. To this purpose, two new sound works by the author, *Destructive Passages One & Two* and *rise.risset*, are discussed before some final discussion about future works.

2. IMPOSSIBLE SOUNDS

Impossible sounds are auditory illusions which imply an impossible sonic behaviour. Shepard tones create the effect of perpetually rising or falling pitch motions. This idea was then translated to the temporal realm. Risset rhythms sound as if they are perpetually accelerating or slowing down.

2.1. Shepard Tones

The use of Shepard tones has become prevalent in a range of different sonic expressions and mediums. The Shepard tone, named after Roger Shepard, is an illusion of perpetual pitch motion (Shepard, 1964). The illusion creates a set of musical notes or tones in which the pitch relation between the notes is perceived as cyclical rather than linear, disrupting our normal sense of low and high. The tone is perceived as eternally rising or falling by using multiple octaves of tones superimposed over each other. The amplitude of these tones is controlled to keep a constant focus on the middle of spectrum with a stationary Gaussian envelope (Vernooij 2016). As the pitch of the tone moves further away from the centre, it decreases in volume, and as it enters the perceptive field from below, it slowly increases in volume. This is carefully controlled so that at the end of a complete octave cycle, the sound is spectrally identical as at the beginning, creating an eternal perceptual cycle.

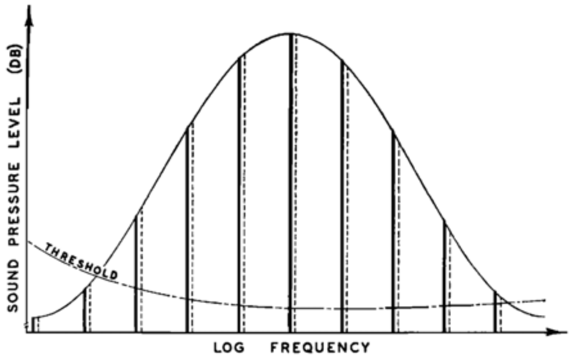

Figure 1. Spectral envelope of a Shepard tone, with the dotted lines showing the direction of a Shepard scale.

Using the new audio technology of the 1960's, Jean-Claude Risset expanded the potential of this illusion by developing a variant of Shepard's discrete scale for continuous gliding tones, now known as the Shepard-Risset Glissando (Risset, 1986). The computer generated synthesised tones opened up the possibilities of the illusion, and has become the more common presentation of the Shepard tone.

The experience of the Shepard tone has been likened to this impossible circularity of the Penrose stairs (Penrose and Penrose, 1958). The stairs share this impossibility of eternal cyclic motions, with four 90-degree turns which form a continuous loop. This means that a person could climb them but never get higher or lower. This impossible architecture was influenced by, and influential to, M. C. Esher who in 1960 created the lithograph print *Ascending and Descending.* The impossible form sits at the top of a building with people walking up and down the never-ending staircases.

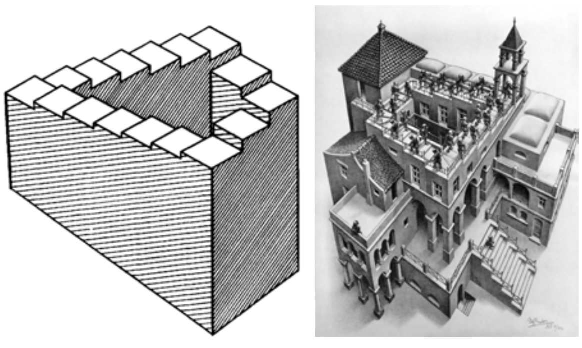

Figure 2. *Left* - Penrose stairs, *Right – Ascending and Descending* – M. C. Escher.

The use of Shepard tones and the Shepard-Risset Glissando has become widespread with some scholars arguing that its musical roots can be heard in the pitch circularity of pieces written as far back as 1550. These works show similarity in their use of a constant upwards or downwards pitch trajectory, which is negated by octave doubling to return to an initial point. Perceptually, this circularity is not as illusory as the Shepard tone, as it's much easier to trace the individual movement of the layers.

The affective element of the Shepard tone makes it a versatile sound design tool in films. Film composer Hans Zimmer and Director Christopher Nolan, have often used the illusion in their films to create tension and suspense. In *Dunkirk* (2017), the eternal upward motion supports the increasing tension throughout the movie of the three intertwined story lines. In *Inception (2010)*, the illusion supports the themes of surrealism and questioning of reality that lies at the heart of the film. The Batpod in *The Dark Knight Rises* (2008), uses a Shepard tone for its engine noise to sound as if it were continuously increasing in speed (Jackson, 2008).

The illusion has also been used in popular music, with post-rock band Godspeed You! Black Emperor's album *F♯ A♯ ∞* using a Shepard tone as an opener, and Pink Floyd's song *Echoes* concluding with one. Austrian composer Georg Friedrich Haas utilizes the effect in his large ensemble piece *In Vain (2000).*

In another context, the Shepard tone has been used to show another peculiarity of our pitch perception. Diana Deutsch conducted a perceptual psychology experiment in which participants listened to two Shepard tones played sequentially and spaced a tritone apart (Deutsch, 1986). In each case, they reported whether they heard the two tone sequence as ascending or descending. Many striking observations were drawn from this experiment. The participants pitch perception wasn't absolute, but more relative, with the pitches being organized in a circle. Consistently, participants perceived tones in one region of the pitch circle as higher, and those in the opposite region as lower. Which region was ascending and descending differed largely between participants. Although the tritone paradox doesn't feature in many artworks or music, it does unveil one of the subjectivities of our cognitive processing of sound. The wide range of responses is idiomatic of many of these illusions.

2.2. Risset Rhythms

Jean-Claude Risset was instrumental in expanding the potential of the discrete Shepard scale through developing the continuous Shepard-Risset Glissando. Risset's research didn't stop there, as he created a similar illusion in the temporal domain, although he credited Kenneth Knowlton with being the first to synthesise the effect (Risset, 1986). Through an analogous method, Risset synthesised rhythmic phrases that are perceived as eternally accelerating or decelerating. Instead of multiple octaves being superimposed, multiple versions of the same rhythm are superimposed at different tempo divisions. The stationary Gaussian amplitude envelope is linked to tempo, and keeps the centre layer the loudest, with the outer layers being progressively attenuated.

Risset himself explored these paradoxical rhythmic motions in multiple works. *Contre Nature* (1996) for percussion and fixed media uses multiple rhythmic octaves of two times, four times and eight times as fast to create an eternally accelerating trajectory. Risset expanded this idea to having musical sections that nested contradicting temporal trajectories. *Moments newtoniens* (1978), *Mirages* (1978), *Electron-Positron* (1989), all have rhythms that speed up constantly, yet are slower at the end than where they started at the beginning. Risset also explored the pitch equivalent to this in *Moments newtoniens,* and *Mutations,* where the pitch seems to ascend, yet eventually is lower in pitch than where it began. Other works which explore Risset rhythms include Autechre's *Fold4, Wrap5,* which uses extended periods of decelerating Risset rhythms.

The musical application of Risset rhythms haven't been as explored as their pitch counterparts. This may be for many reasons, with Dan Stowell suggesting that the complexities of managing accelerating fractal rhythms within compositional and sound-design environments may have held back their usages (Stowell, 2011). In an attempt to increase their accessibility and help facilitate their use in compositions, Stowell has derived mathematical expressions for scheduling accelerating Risset rhythms.

3. NON-LINEAR SOUNDS

The aural sense is a non-linear filter. This means that it doesn't possess the three main characteristics of a linear filter which are as follows. Firstly, the output of the filter must never contain any frequency component that was not present in the input signal. Secondly, if the amplitude of the input to the filter is changed by a certain factor, then the output should also change by the same factor. And lastly, if a number of sine wave inputs are applied to the filter simultaneously, then the resulting output should match the output that would be produced if the inputs were presented separately, and their individual outputs summed (Mather, 2009).

Non-linear sounds are a group of sounds which reveal the non-linearity of our auditory perceptual processing. They highlight how our hearing differs from a transparent linear filter, and the way it colours our experience.

3.1. Combination Tones

Combination tones are an illusory tone which are a by-product of the interaction of two real tones. There are two types: sum tones whose frequency is equal to the summation of the two real tones. And difference tones, whose frequency is equal to the difference between the two real tones. Combination tones have an important place in history, as they were one of the auditory phenomena that spurred investigations into the non-linearity of the ear. Their discovery is attributed to violinist-composer Giuseppe Tartini, who used the third tone in correcting faulty intonations of double stops on the violin (Jones, 1935). Through making the third illusory tone consonant with the two real tones, he was guided in finding the intonation of the open strings.

The musical uses of combination tones have been varied through electroacoustic and instrumental music. The consideration of the relationship between partials and sine tones makes combination tones well aligned with the Spectralist school. They form a driving melodic tool in Tristan Murail's *Ethers* (1978), with the purity of the solo flute being supported by different combinations of the ensemble. Claude Vivier, who was heavily influenced by the Spectralist school, explored combination tones as a timbral device, to produce a distinctive spectral harmony that became a core element of his compositional voice (Gilmore, 2014). Ben Hjertmann has made combination tones as harmonic materials the centre of his doctoral thesis (Hjertmann, 2013), producing a new work for small ensemble, *Angelswort* (2012), and vividly analysing Ezra Sims's *Quintet* (1987).

In the electroacoustic world, La Monte Young has extensively explored relationships between pure sine tones, and often created difference tones in his piano and installation works. *Dream* House (1995) creates a physical sound environment that offers the audience dynamic autonomy to experience and explore the different tones and their effects. Various wavelengths of static tones ricochet around the room, projected from loudspeakers, and blend to make a complex typology of pure tones and combination tones. Walking around the space, different tones blend at different spatial nodes, and even a slight movement of the head can create a different effect (Grimshaw, 2011).

3.2. Otoacoustic Emissions

Heavily related to combination tones, Otoacoustic Emissions (OAEs) are sounds which the ear makes itself. The emission is not an illusion, but instead an artefact of the physiology and non-linearity of the auditory system. OAEs are sounds that are generated from within the inner ear. This phenomenon is related to the amplification function of the outer hair cells in the cochlea (Mather, 2011).

Otoacoustic Emissions can be provoked through three different types of stimulus. Stimulus Frequency OAEs are created by a single pure tone, with the resulting tone matching the stimulus tone (Miller et. Al, 2004). Transient-evoked OAEs are stimulate by a loud click sound (Kemp, 2002). Lastly, Distortion product OAEs are created when a pair of closely spaced tones with a ratio between 1.1 and 1.3 are presented with high intensity (Hall, 2000). This form of OAE's has had the most musical exploration, as they create a different tone to the stimulus, which allows for the listener to be able to easily distinguish between the two pure tones and the third artefact tone.

Maryanne Amacher's seminal work with OAEs, *Head Rhythm/Plaything* from her album *Sound Characters (Making the Third Ear)* creates arpeggios of OAE's that move around the head in disorientating patterns. The localisation of these sounds creates an interesting contrast between the 'outer' sounds, and 'inner' sounds, creating a complex spatial counterpoint between real tones and generated tones. Amacher discussed this exploration of the spatial elements of the two types of tones as *perceptual geography.* She writes 'I distinguish *where* the tones originate, in the room, in the ear, in the brain, in order to examine this map and to amplify it musically' (Amacher, 2004).

In a similar exploration of the spatial elements of OAEs, Alex Chechile has recently composed a series of pieces entitled *On the Sensations of Tone* (2010). The works mix electronic and acoustic sources, using OAEs to invite the listener into an exploration of their listening space. Through slight head movement, OAEs will appear, disappear, and change timbre. Macroscopic and microscopic listening can be achieved by shifting attention between the primary tones and the ear tones. The effect can be enhanced by cupping hands around one's ears.

In composing *On the Sensations of Tone,* Chechile has developed *The Ear Tone Toolbox*, a collection of Max externals, VST plugins, and patches for the hardware OWL synthesiser, that offer creative control over OAEs (Chechile, 2015). The toolbox allows the user to input various combinations of evoked distortion products and acoustic primary tones, which are then synthesised in the software. This contribution to the field will allow more composers access to the creation and exploration of OAEs in their music, and may inspire a range of new works.

Other composers have explored different elements of the experience of OAEs. Jacob Kierkegaard makes them the explicit subject of his 38-minute work *Labyrinthitis* (2007). Kirkegaard has presented this work both in stereo form, and as a 16-channel sound installation, with the speakers suspended in a contracting spiral, modelled on the shape of the cochlea. The piece begins with two pure tones that excite a singular OAE. This precise tone is then used as the next acoustic tone, starting a process of cascading interplay between acoustic and OAE tones.

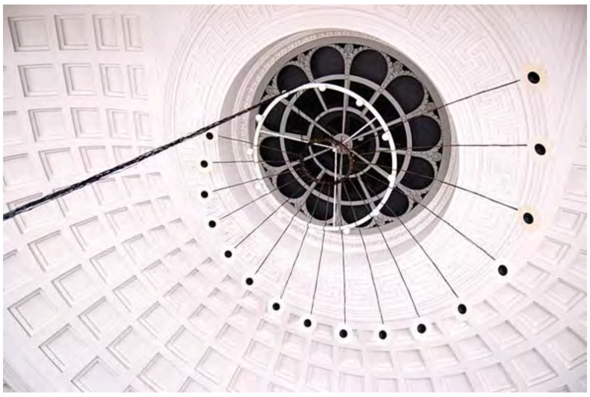

Figure 3. *Labyrinthitis* - Jacob Kirkegaard

One of the most intriguing elements of OAEs is on its effect on how we conceptualise the auditory system. Often, the ear is thought of as a passive, submissive sense organ. In comparison to our visual sense, our aural sense seems to be continuously engaged, always open to stimulus from all directions, and unable to be turned off. We can look away, but there is no sonic equivalent, and unlike our eyes, 'we have no ear lids' (Schafer, 1977). OAEs turns the ear into a dynamic element in the system, both receiver and producer, and problematizes this conception of it as a passive receptor.

3.3. Zwicker tone

Similar to the transient-evoked OAEs, the Zwicker tone is an auditory illusion produced in response to noise. In the case of the Zwicker tone, broadband noise with a spectral gap in the middle is presented for several seconds. The auditory illusion appears once the noise is removed, and a pure tone that falls within spectral gap is audible for up to six seconds. This is an interesting case of non-linearity, as the Zwicker tone demonstrates the auditory system hearing a sound which is not in the stimulus.

The Zwicker tone has not, to the authors knowledge, been explored in sound art yet. There may be multiple driving factors for this. The illusion needs extended exposure to loud noise to be provoked, which may cause discomfort for listeners. It is also a subtle experience, which may be hard to detect the nature of the illusion without previous knowledge.

However, this does not mean the Zwicker tone does not have potential, as it shares qualities with other sensory illusions which have been explored in art. A notable commonality is with the visual afterimage. This phenomenon forms an image that continues to appear in one's vision after the exposure to the original image has ceased. The nature of the visual afterimage ranges depending on the stimulus, including dark spots, illusory motion and changes in colour (Bayne et al., 2014).

Figure 4. *Your Blue Afterimage Exposed* – Olafur Eliasson

The colour afterimage forms the perceptual material of Olafur Eliasson's *Your Blue Afterimage Exposed* (2000) shown in Figure 4. An intense square of colour is projected onto the wall, flooding the room in a vivid orange. At timed intervals, the projector is turned off, suddenly depriving the visual senses of this immersive light. The complementary blue colour appears in the visual perception of the audience, creating a square that matches the orange one that has just vanished. The move from outside stimulus, to internal perception is heightened by the fact that now, when the audience looks away, the blue square follows their gaze, revealing itself as part of their subjective perceptual processing.

3.4. Missing Fundamentals

Combination tones and Otoacoustic Emissions aren't the only sounds that provoke our cognitive processing to create new notes. Complex harmonic sounds are made up of a fundamental frequency, and a series of evenly spaced partials. The missing fundamental illusion arises when a set of partials are presented that lack the fundamental frequency. The listener will still perceive the lower fundamental, even though it is not present. This reveals an element of the way we perceive pitch. The brain can infer the fundamental pitch from the relationship between the partials (Cariani & Delgutte, 1996; Schwartz & Purves, 2004).

The experience of the missing fundamental is surprisingly common and will most of the time go unnoticed. Guitars, violins, and timpani all produce the illusion which helps to create the low perceived frequencies than their physical resonant bodies can support (Howard & Angus, 2006).

The missing fundamental illusion is also present in the technological reproduction of sound. Telephone conversations create the illusion, as the small speakers in telephone headsets can only generate frequencies in the range of 300 Hz to 3 kHz. Male voices can have fundamental frequencies of 150 Hz, and these low frequencies are still perceived because of the illusion (Mather, 2011). The effect has been utilized in a range of commercial D.S.P plugins which seek to allow speakers to seemingly produce loud bass frequencies that are lower than their technological limits. Through using the effect, the loud bass frequencies are implied by creating precise partials, which means that the dynamic range isn't consumed by large amounts of low frequency energy (Grimm et al, 2001).

Due to the missing fundamental effect usually going unnoticed, it hasn't been thoroughly explored in musical works. An exception again comes from La Monte Young, through his exploration of different tuning schemes in his highly influential work, *The Well Tuned Piano* (1964). Through retuning the strings to a seven-limit just intonation scheme, the combination of notes can create the effect of implying an unplayed fundamental (Gann, 1993). John Schaefer describes experiencing this passage as 'keyboard filigrees and shimmering harmonics …a strongly implied drone, although since it's several octaves below the range of the piano, it's never actually heard' (Schaefer, 1987).

3.5. Binaural Beating

Another form of non-linearity in our auditory system is displayed by the binaural beating effect. Similar to combination tones, binaural beating is caused by the relationship between two pure tones. In this case, the two pure tones must be below 1500 Hz and have less than 40 Hz difference (Licklider et al. 1950). When these tones are presented dichotically - one tone in each ear - a third tone is perceived. This third tone is not perceived like a normal pitch, instead it is often heard as a beating effect, amplitude modulating the other two tones and creating an illusion of motion in the sound. The interaction between the processing of these two sounds creates a confusion in localisation. As Gerald Oster describes it, 'Listening to binaural beats produces the illusion that the sounds are located somewhere within the head (Oster, 1973).

This illusory localisation unveils one of the mechanisms by which we are able to sense the direction of sounds. Low-frequency signals are localized primarily by detecting the difference in phase – the between the sounds reaching the two ears (Oster, 1973). At higher frequencies, the size of the head is larger than the length of the soundwaves, so the difference in phase becomes obscured. At these frequencies, we rely more on the interaural level and time differences to sense the location of sounds (Wallach, 1940). This change in method of detecting location explains why binaural beats must be below 1500 Hz, as it is the confusion in phrase difference in which the illusion manifests.

Many of the musical explorations of binaural beats have been through their supposed potential for brain entrainment. This is the potential for the listener to synchronize the electrical activity in ensembles of cortical neurons in their brain to an external stimulus (Will and Berg, 2007). The scientific testing of this has been problematic, and some researchers have found 'no effect of binaural beat frequency eliciting a frequency following effect in the EEG' (Vernon, 2014). Regardless, many websites and services have been created which devote themselves to binaural beats, with long pieces claiming to awaken intuition, universal healing, and open the third eye.

Binaural beats have a great potential for sonic exploration as they create a unique experience of sound seemingly emanating from within the listeners head. This play with spatialisation has a rich history in electroacoustic music, as will be discussed in the next section, Phantom Sources.

4. PHANTOM SOURCES

One of the most commonly used auditory illusions in sound art is spatialisation of sound sources. Spatialisation of sound has been a core aesthetic element in the development of electroacoustic music. A range of linguistic tools for describing space have been theorized, and many new technologies have been created. These tools seek to afford the ability to explore space as an expressive parameter. A full discussion of this large field is outside the scope of this paper, however, many of the technological advances are informed by the cognitive processes involved in locating the source of sounds.

The spatial position of sound is not represented directly in our auditory pathway (Oldfield, 1984). Therefore, spatial cues must be derived by the nervous system from different relationships within the sonic stimulus. The exact nature of these cues and the way spatial information is derived from them, has been the subject of research for many decades. This research has led to a thorough understanding of our capacity to determine the location of a sound, from the sound alone. Binaural cues, which stem from differences in stimulus between the two ears, provide the major cues to localising sound on the horizontal plane. Two major binaural cues have been identified. These are differences of time (either onset differences or phase differences, depending on the frequency) and differences of intensity (Mather, 2011). However, with these binaural cues, there are multiple locations at which the sound could be originating from. For any one binaural cue there is a range of potential positions which could account for the same pattern of interaural differences.

Additional cues are derived from the spectral modifications that the external ear has on sound. The pinna act as a sound filter, selectively modifying the amplitude and phase of frequencies above 6 kHz. The asymmetrical shape of the ear means that the modification of sounds depends on the sound direction (Watkins, 1978).

Through understanding of the processes involved with auditory localisation, audio technologists and composers have been able to use and create new tools that make space a dynamic, compositional parameter. Through precise control of amplitude and filtering between multiple loudspeakers, sounds appear to be created from locations between and beyond the loudspeakers. This is not limited to stereo, with complex algorithms like Vector-Based Amplitude Panning and Wavefield Synthesis expanding this to the full performance space with large arrays of loudspeakers. These techniques also expand to three-dimensional space making elevation a compositional parameter.

5. NEW WORKS

Through investigating auditory illusions and artefacts as an artistic material, the author has created two new works: *Destructive Passages One & Two*, and *rise.risset*. Both works seek to offer a rich perceptual experience for the audience. They invite the audience to meditate on the subjectivity and uniqueness of their own perceptual experience through an interplay between illusion and simple materials.

5.1. Destructive Passages One & Two

Destructive Passage One & Two is a sound installation that explores the multiple artefacts in our perceptual processing of two pure tones. Through the two pairs of tuning forks that are slightly detuned from each other, the work provokes binaural beating and combination tones. Solenoids strike each fork, with a bamboo resonating cavity channelling the sound to a small area of space.

There are two different arrangements. The first channels the sound together, colliding the sound waves into each other, creating destructive and constructive interference. The difference between the two tones is 3 Hz, which manifests itself as amplitude modulation. Due to the small 3 Hz difference, instead of hearing the third illusory tone directly, we hear its effect on the other two tones. It creates a slow beating pattern, as the volume swells in and out three times a second. Due to the small space at which the two sounds are channelled into each other, this arrangement invites the audience to listen in with one ear. As they move their head, the blend between the two tones changes, controlling the intensity of the illusion effect.

Figure 5. *Destructive Passages One & Two* – Blake Johnston

The second arrangement invites the audience to listen to the two tones dichotically. The two resonating cavities point straight forward, created a gap slightly larger than the average head. The smaller 1.5 Hz difference between the tuning forks in this arrangement creates binaural beats. The audience can move their head, blending the two tones together, creating the illusory localisation of the tones moving around the head.

Figure 6. *Destructive Passages One & Two* – Blake Johnston. *Right* – Arrangement One. *Left* – Arrangement Two.

Both arrangements give the audience the autonomy of experience the work on their own terms. A button is pressed by the listener to actuate the solenoids, striking the tuning forks into motion. The illusions are contained to a node in space, allowing the audience to be free to move their head and investigate the space, changing the blend and intensities of the effects. This affordance of autonomy reinforces the demystification of the effect, as the audience is in control of many of the elements. They can see that what they are experiencing originates from the two simple tuning forks in front of them.

5.2. rise.risset

rise.risset is work for Bridget Johnson's *speaker.motion* (Johnson, 2017), a quartet of mechatronic speakers that can rotate through space to change the directionality of the speaker. The speakers can be controlled in real-time by MIDI messages, and can rotate and tilt simultaneously, allowing for precise positioning to any direction.

rise.risset explores the themes of ambiguity in localisation, sound source, and trajectories. The piece positions the four *speaker.motion* units in a square, enclosing the audience. The work is structured in three sections. The opening section explores the ambiguity in the cause of the sound. The ensemble creates mechanical noises as the speakers rotates and tilts. The piece starts with just these noises, using sharp twitches in rotation to create a rhythmic pattern. The noise itself is not loud, but audible, and as this section progresses, recordings of these mechanical noises are reproduced by the speaker. This amplifies the magnitude of these mechanical noises and the ensembles physical presence. This rhythmic material then leads into the next section.

The rhythmic pattern created in the opening section becomes the focus in the next section, with sharp noise bursts reinforcing the mechanical twitches. These bursts slowly fade in, blurring their entry, and eventually become the foreground. This rhythmic pattern becomes the basis of a risset rhythm, creating an impossibly accelerating trajectory. The layers are distributed across the speakers. This creates another layer to the experience of the risset rhythm, as the main layer which is perceived as the focus of the rhythmic figure slowly shifts around the ensemble. As this section comes to a close, the speakers start to slowly rotate, creating moments where the risset rhythm disintegrates into its multiple streams, as the amplitudes of the noises bursts are filtered by the space. This also acts as transitional material, moving into the last section.

The final section of the piece balances the energetic accelerating risset ryhthms with perpetual downwards pitch trajectories. The *speaker.motion* units create clear pitches when rotated at a constant rate, which is correlated to the speed of rotation. The four units are rotated slowly at different speeds, with the pitched noises tuned to create a chord. These noises become the pitch material for the last section. This blurs the cause of the sound, similar to the opening section, where the audience is unsure whether the mechanical noise of the system is what is being heard, or the speaker producing the sound is. The four speakers start to produce descending Shepard tones, using the pitched noise as their base. As each unit is rotating at different speeds, the audience is bathed in multiple layers of descending trajectories, which swirl around the performance space. This heightens the motion of the Shepard tones, constantly shifting the attention of the audience around the room. This downwards descent eventual exhausts itself, slowly fading out, with the speakers stopping one by one.

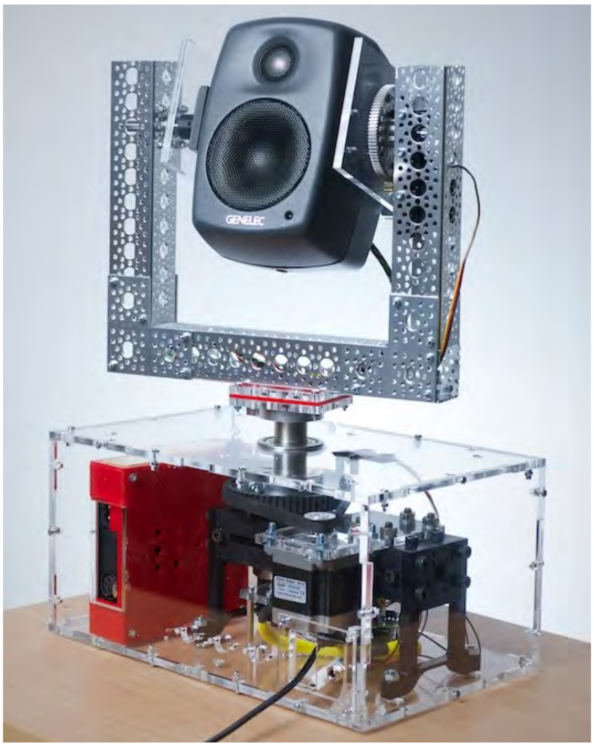

Figure 7. *rise.risset* – Blake Johnston for four *speaker.motion* units, Bridget Johnson's mechatronic speaker array.

6. FUTURE WORK

As evidenced in this paper, there is a broad range of auditory illusions and artefacts, which offer interesting insights to our perceptual processing, and potential as materials for artworks. The collection of works discussed and collected in this paper shows that there is a strong interest in using these themes in new sound works.

However, these materials are far from being exhausted. New tools like Alex Chechile's *The Eartone Toolbox* offers greater accessibility to composers and artists to explore Otoacoustic Emissions. Likewise, the ever developing field of new interfaces for musical expression shows advancements in the expressive control of space, through systems like Bridget Johnson's *speaker.motion*. The potential in these materials lie in their ability to create unique experiences for the audience that unveil and provoke questions about the subjectivity of their own perception of the world.

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A 3D PRINTED HYBRID SAXOPHONE MOUTHPIECE FOR DATA COLLECTION

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ABSTRACT

In the past few decades there have been explorations on hybridization of acoustic and electronic instruments in order to achieve new musical possibilities. These kind of hybrid instruments, also known as hyperinstruments, rely on the use of new technologies, sensors, cameras, microcontrollers, and other devices, as well as computers and software, to collect and process data to generate new audio. This paper documents the authors' own exploration on hyperinstruments and the search to access new instrumental techniques for the saxophone, and offers a detailed description of the design of a 3D printed saxophone mouthpiece which combines acoustic and electronic characteristics to collect data from the performance, aiming to control live electronics. The mouthpiece's performance is characterised and the potential to use the collected data for pedagogical purposes is also considered.

1. INTRODUCTION

In recent years, 3D printing technology has allowed new developments in design throughout a wide spectrum of fields. In the field of music and acoustics, this new technology has also opened new possibilities allowing for accessories, instruments, resonators, replacement parts, protective cases and other related items to be developed. Perhaps the importance of 3D printing technologies for musical research lies on the fact that these new printers can produce prototypes and final products with a relative ease of construction, unlike working in the old-fashioned way by handcrafting the instruments or parts out of natural materials (typically wood). It is well known that luthiers, woodwind and brass instruments makers, as well as other professionals in similar fields, learn their craft over many years, and a musician or researcher is usually not skilled to build musical instruments, repair them, build new parts or developments, therefore slowing down any projects in this field. Not only are the new 3D printers allowing more professionals to access easy and fast prototypes, but their low price has opened the doors for the DIY amateur enthusiast.

There are documented projects of printed models that have furthered the developments of musical instruments and acoustic investigation. The authors catalogue these 3D printed models in six categories: protective accessories (shells, cases, pads, caps, etc), repairments (knobs, string pegs, bridges and other small part replacements), enhancements (pickup holders, shoulder rests, inserts, etc.), replicas, customizations and innovative designs. Many of these models, mostly from DIY projects, are shared as creative commons in specialized webpages such as thingiverse.com, yeggi.com, grabcad.com and many others. Other scholarly projects focus on researching musical and acoustic issues rather than practical ones, such as producing microtonal flutes (Dabin et al. 2016) or a multi-sized shank in a trumpet mouthpiece (Leitman and Granzow 2017) for acoustic inquiry.

This current project takes advantage of the 3D printing technologies with a model that fits in the category of customizations, aiming to collect data on the air pressure blown into the saxophone. This mouthpiece, along with other developments, will be used in the creation of a hypersaxophone with the goal of allowing saxophonists to access new instrumental techniques.

This paper examines previous developments by other authors, and the influence those projects had on the development of the mouthpiece. Detailed information on the design and tests is also discussed to offer an overview of the project and its potential, and possible future uses of the mouthpiece.

2. RELATED WORK

In recent decades, new enhancements have been added to musical instruments, generating two new categories of musical instruments: hybrid instruments and hyperinstruments. Hybrid instruments are those instruments that combine different materials in their construction, characteristics of two or more instruments, or different ways of producing sound (e.g. electroacoustic instruments). On the other hand, in hyperinstruments the audio output is processed by a logical system loaded in a computer or microprocessor. There have been many examples in which hyperinstruments or hybrid instruments have been developed by means of combining traditional acoustic instruments and new technological developments such as sensors, microprocessors and computers.

In previous works, researchers have demonstrated that it is possible to collect data on different aspects of instrumental performance through the use carefully designed systems. As Matthew Burtner described it, these systems “convert the performance data into a continuous data stream” (Burtner 2002) which could be used to control digital audio processing, to study the performative practices, to understand the acoustic phenomena or to gather information useful for pedagogical purposes. Despite the fact that there have been a good number of projects dealing with woodwind or brass instruments, very few of these designs deal with the issue of air flow through the body of the instruments and how to quantify the energy carried by the air.

Gathering data from air flow can be very difficult as disturbing the air column inside a musical instrument results in undesired affectations to the overall acoustics of the instrument. In consequence, a design where all the data collection happens away from the air column running inside the instrument is the only feasible option. This, however, raises different problems on different aerophones as the way the air is blown into the instrument varies. In instruments with a blowhole, such as flutes, the air is blown across a sharp edge of the blowhole. This system allows for external data collection of the airflow. In whistles, single reed instruments, double reed instruments, brass instruments (cup mouthpiece) and pipes, acquiring this information can be difficult as the air travels directly from the mouth to the inside of the instrument.[1]

In research undertaken at McGill University, it was proven how difficult but useful it can be to gather air flow information and reuse it as a musical control variable. In this 2005 project, air pressure sensors are mounted around the mouthpiece gather the data. However, this system can be unreliable since the flute performative practices sometimes require a change of the angle in which the air is blown into the instrument, resulting in variation of the air pressure blown into the sensor (Da Silva, Wanderley, and Scavone 2005).

Other projects aiming to measure the energy of the air stream utilize a microphone which gathers information on the quality and dynamics of noise produced by air to obtain comprehensible data of the energy carried by the air stream. The use of microphones to obtain information on the air blown has been very successful in projects such as Smule, an iOS app which has been successfully used by thousands of users around the globe (Wang 2009).

Projects such as the SABRe (Schiesser and Schacher 2012) deal with problems related to reed instruments. In this case, it becomes impossible to use a microphone or an air pressure sensor inside the body of the instrument or at the end of it since foreign objects inside the instrument would disturb the air column, and placing the data collector at the end of the instrument does not yield accurate results since the air stream’s energy is lost through the various holes of the instruments depending on the fingerings. In this particular project, its authors developed a system in which a small hose mounted on top of the instrument redirects a portion of the air stream into an air pressure sensor, obtaining accurate readings in every situation. In this case the sensor, being mounted on top of the mouthpiece, is close enough to the air stream source (player’s mouth) to ensure that no energy (pressure) is lost before the sensor reading is done.

Another way to achieve accurate acquisition of data was explored in a joint effort between Universitat Pompeu Fabra and Standford University, where it was demonstrated that modifications to the mouthpiece of an alto recorder to redirect a portion of the air flow into an air pressure sensor was possible (Garcia et al. 2011) by creating conduits in the body of the mouthpiece to redirect a portion of the air stream into a sensor.

Based on these previous developments the authors have modified a 3D model of an alto saxophone mouthpiece (shared on thingiverse.com) to produce a new version that features modifications that allow a portion the air stream to be redirected into an air pressure sensor, thus obtaining accurate readings without disturbing the air column inside the instrument at the same time as it provides a comfortable playing experience.

3. SYSTEM OVERVIEW

The hybrid saxophone mouthpiece has been designed with the purpose of offering a tool that can be used both to perform and to collect data about the performance. The collected data can eventually be used in different situations which may include information gathering for performance study or more practical goals such as controlling diverse parameters inside a software capable of communicating via serial or MIDI protocols.

3.1. 3D Design

The first step in developing the mouthpiece was considering the fact that introducing an object inside a saxophone causes disturbance in the air column, therefore changing the quality of the sound, affecting the intonation, producing “squeaks”, or completely stopping the sound. Based on past projects, listed above, the authors decided to work with a 3D design that would feature an alternate conduit in the body of the mouthpiece that would permit data collection without affecting the air stream flowing through the mouthpiece and final air column inside the saxophone.

The mouthpiece is an adaptation of the *Alto Saxophone Mouthpiece* designed by Thingiverse user Allanarps (Allanrps 2011). The original design is based upon a Yamaha beginner mouthpiece, with similarities including bore length and shape, facing width, tip opening and basic length measurements, featuring a flat baffle and squared throat (bore).

The adaptation keeps the basic shape of the interior with the same dimensions in the chamber of the mouthpiece, facing width and bore shape, which ensures that the air column running through the chamber behaves in the same manner as in the original design. The changes made to the design include a shorter tip opening of 1.8mm

[1] For a more detailed classification of aerophones: (von von Hornbostel, Sachs, and Montagu 2011)

(original is 2mm) and a thicker beak that allocates a small conduit running through the body of the mouthpiece to an added section in the back in which a sensor is mounted to measure the air pressure. See Figure 1 for a comparison between the original design by Allanarps and the adaptations made to it.

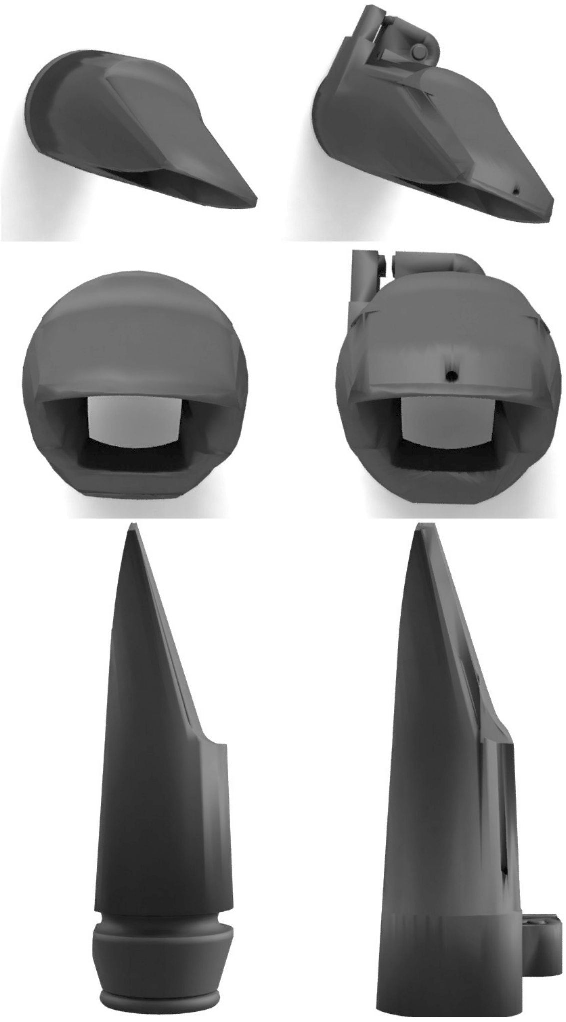

Figure 1. Comparison between the original 3D model (left) and the new version (right) with adaptations to allocate a pressure sensor and an alternate air conduit.

As mentioned before, the conduit inside the body was designed to allow comfortable playing with no disturbance to the air stream and air column, and to achieve this goal a minimal amount of material was added to the top of the beak of the mouthpiece to accommodate the conduit. In total, 2mm of thickness was added to the beak, of which a 1mm radius cylindrical opening is found at the front/center of the beak, where the structure is weaker because of its dimensions. Further back, the conduit opens more to fit the dimensions of the sensor at its back end (see Figure 2). There is also a small side canal that allows moisture and saliva to escape the system. This opening can be blocked or opened if desired with wax or tape. Further testing will determine whether this side opening is necessary.

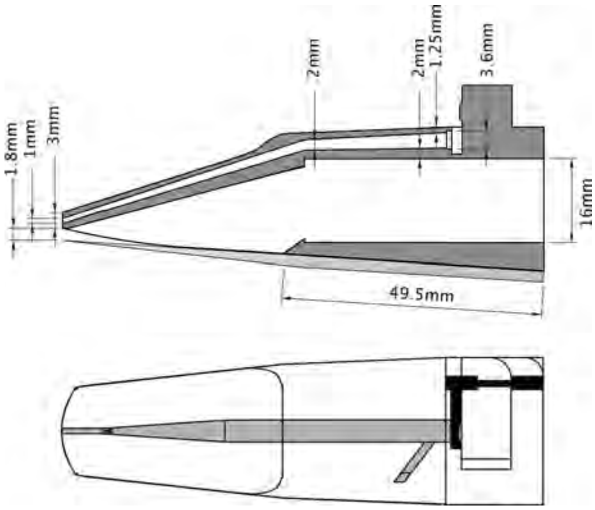

Figure 2. Interior of the mouthpiece. The top image shows a slice of the mouthpiece where the chamber and conduit are shown in white. The bottom image shows the conduit and side canal in gray. The area designed to position the sensor breakout is colored in black.

3.2. Components

The Hybrid Saxophone consists of two main components: the 3D printed mouthpiece and an electronic barometer sensor BMP180.

The 3D model, previously described, can be printed in a variety of materials, including organic-based (wood) and other plastic and polymer based materials, many of them resembling ebonite, a common material used in the fabrication of mouthpieces. For the first printing trials, an Up Mini filament deposition modelling 3D printer was used. For the printing material, ABS (acrylonitrile butadiene styrene) has been used due to its durability, ease of use and price.

To measure the air pressure, various kinds of sensors were considered. Unlike previous projects, this one has the advantage of 3D design customization which allows the opportunity to fit any reasonably sized sensor. The chosen sensor is a BMP180 designed by BOSCH as a barometric pressure sensor commonly used in applications such as indoor navigation, GPS-enhancement for dead-reckoning, slope detection, etc., sport devices, (e.g. altitude profile), weather forecast, vertical velocity indication (rise/sink speed) and others (“BMP180” 2017). Considering the applications for which the BMP180 was designed, this is not the most obvious choice of sensor, however, due to the flexibility of design it was easy to fit this sensor in the mouthpiece and match it with the end of the alternate air conduit.

The BMP180’s most relevant features are: 300-1100 hPa pressure range, an average current consumption of

650µA that can go down to 3µA, supply voltage VDD of 1.8V to 3.6V, a relative accuracy pressure of ±0.12 hPa, and the use of the I^2C protocol at a 3.4MHz transfer rate (BOSCH 2015).

Unlike most sensors designed to measure air pressure, the BMP180 doesn't feature a funnel-like structure to redirect the air into it, which becomes unnecessary with the conduit built into the mouthpiece 3D model (see Figure 3). The BMP180 can be purchased on its own or mounted on different breakout boards. For this project, the GY68 breakout has been chosen because on this design the "hole" that captures the air in the sensor is situated close to one of its edges, which makes it convenient to introduce it in the body of the mouthpiece and reach the end of the conduit. Other breakout boards place the sensor on the center of the PCB, and the use of these boards would translate in carving into the model to reach the air conduit, this could compromise the structure of the mouthpiece.

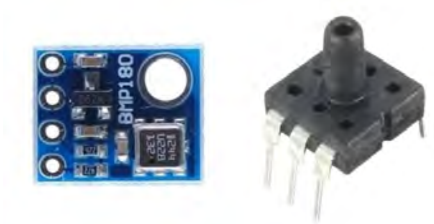

Figure 3. BMP180 Breakout GY68 next to a common air pressure sensor with a funnel-like casing.

The breakout stays in place thanks to a small protuberance on the mouthpiece which matches the screw hole in the breakout. Also, the breakout pins help secure the sensor in place once they are connected to standard 2.54mm connectors. In Figure 4, the sensor is mounted on the printed model, showing the way it "locks" in place. The GY68 breakout design is perfect for handling and replacing the sensor if necessary as it only needs to be pushed into the opening in the mouthpiece designed to allocate it. Therefore, any user can replace it without the assistance of a technician and at a very low cost.

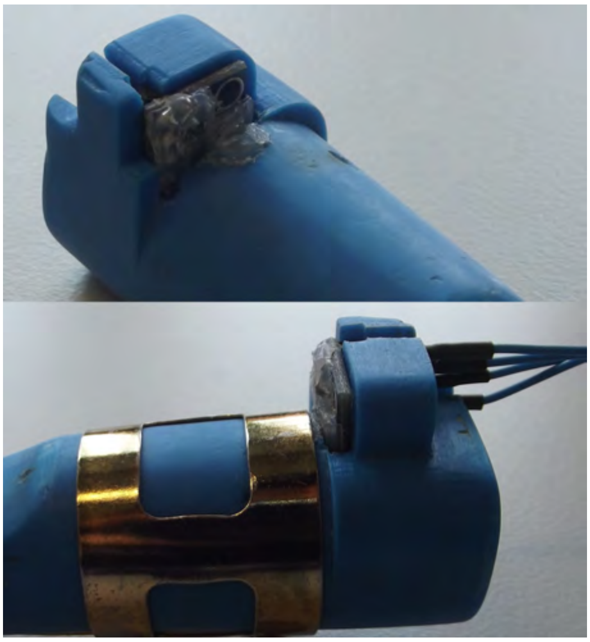

Figure 4. BMP180 Breakout GY68 secured on the mouthpiece. The visible silicone on the breakout protects its components from moisture without affecting the sensor response.

3.3. Board and On-board software

At this stage of the project, the barometric sensor is working together with a Teensy LC board[1], sending data using the I^2C protocol. This board is also capable of communicating using the MIDI protocol without having to implement complex code or hardware development, which opens up the possibility of utilizing the system as a MIDI controller.

The program loaded on the board executes a self-calibration when the system is powered. To calibrate, it firstly determines the ambient temperature, and then sets a current pressure (actual atmospheric pressure) as a baseline value, setting that value to 0. Once these parameters have been established, every iteration of the program loop compares the new results to the baseline value, outputting positive numbers for any value greater than the baseline, and negative numbers to values under the atmospheric pressure. The values are expressed in hectopascals.

The sensor is affected by temperature in a manner similar to woodwind instruments. To address this, the program performs a new calibration every five minutes to compensate for temperature changes that occur due to breathing and blowing into the mouthpiece. The sample rate is at 33 readings per second, but can be changed according to the needs of the project. A faster sample rate could be beneficial to detect attacks more precisely and avoid latency in musical contexts. Another fact to be considered when deciding the sample rate is the delay

[1] For more information on the Teensy LC, visit the developer's website at https://www.pjrc.com/teensy/teensyLC.html

that occurs between the moment when the performer starts blowing and the sonic event, which depends on dynamics, expressivity, the hardness of the reed, the calibration of the instrument's mechanics (to avoid air leaks) and other factors. Further investigation must be done to address this issue.

4. TESTS AND RESULTS

As mentioned before, the goal of designing this mouthpiece is to be used as a key element of a hypersaxophone. For this reason, the performance of the mouthpiece has been tested by using it in common musical practices. In order to test the system, a Max7 patch was designed (see Figure 5). This program receives the incoming data using the USB port. The program updates the data 33 times per second in synchronization to the Teensy's firmware. Then, the data is used to create a graphic profile of the measurements in a Cartesian system representing time (in seconds) and pressure (in hectopascals). The object used in Max7 to create the visuals representing the air pressure is [plot~] set to draw a profile with 33 points per second (indicated by the markers on the X axes) thus creating a representation without smoothing the collected data. The range in both the X and Y axes can be resized to draw a profile that meets the needs of the tests.

Figure 5. Max patch designed to read incoming data.

The characterization program also features a representation of the audio input to compare the morphology of sound (attack, decay, sustain and release) with the pressure readings. It has a monitoring function as well as a recording function which allows users to save an audio file and a screenshot of the soundwave and pressure profile representations for further analysis.

In an experiment made with the help of saxophonists Reuben Chin and Jasmine Lovell-Smith, the system was tested at the Lilburn Studios at Victoria University of Wellington. The setup consisted of the mouthpiece/sensor mounted on the alto saxophone, along with a Zoom H2 microphone, both connected via USB to a Macbook Pro running Max7 on OSX 10.11. The results demonstrated the efficacy of the system using a sensor that is sensitive enough to capture minimal changes in pressure such those produced by the performer's breathing patterns. In Figure 6 one can see the rapid response of the system and the high pressure produced by preforming the slap tongue technique and a regular note in forte dynamic.

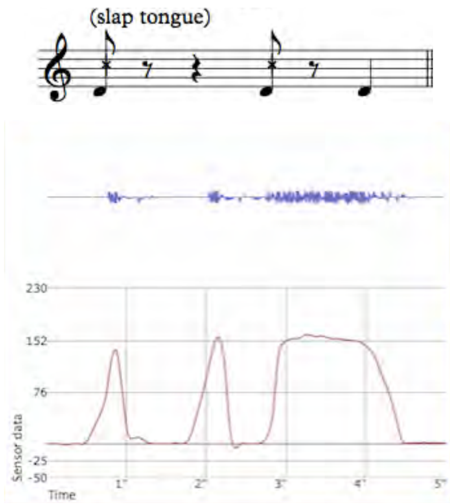

Figure 6. Slap tongue test.

In Figure 7 one can see the pressure change needed to accurately tune notes as the performer ascends or descends within an octave while playing a diatonic scale.

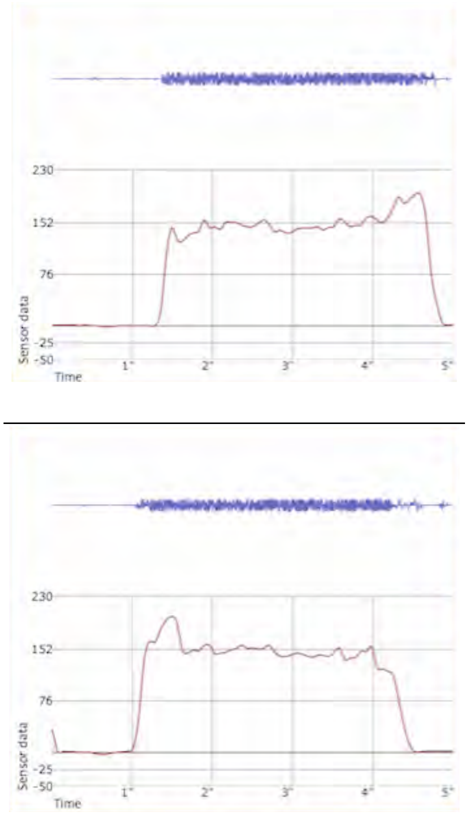

Figure 7. Ascending scale (top) and descending scale (bottom) between B4 and B5.

The system is also capable of demonstrating performance errors to be corrected, which holds promise for future pedagogical contexts. In Figure 8 the graphic shows a well-executed flutter tonguing technique and a failed execution of the same exercise. This example shows how a greater air pressure does not permit the correct execution of this technique.

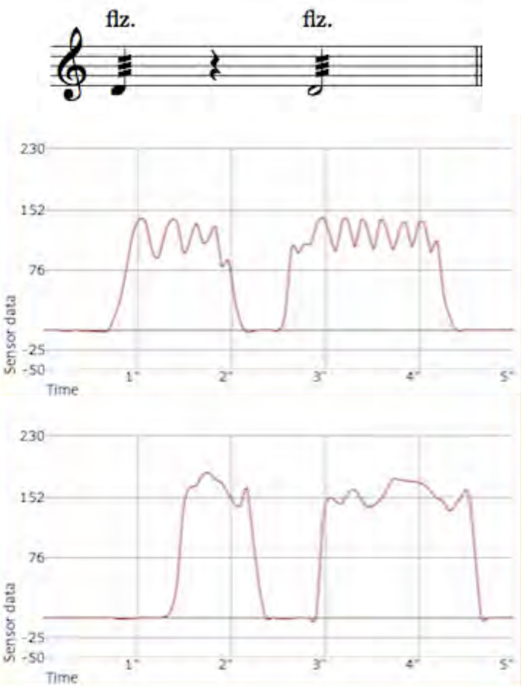

Figure 8. Fluttertonguing exercise (top) and the corresponding sensor reading of good (middle) and poor (bottom) execution of it.

The timbre of the saxophone doesn't seem to be greatly affected when the 3D printed mouthpiece is used. There are changes in the overall spectral content, however this differences in timbre are common even between two mouthpieces of the same brand and model.

The 3D printed model was compared to a Yamaha beginner mouthpiece (in which the 3D model is based). The results show variations of the energy on some of the overtones. Despite these differences, the overall overtone structure of the timbre is constant. In the lower register the differences are minimal, resulting in an almost imperceptible change of timbre. In the higher register the 3D printed model tends to present less energy on the overtones, which results in a less bright sound, but still consistent, stable and controllable. These differences are visually represented in Figure 9 and Figure 10, where a comparison of spectrum profiles is presented. These profiles where obtained from recordings of a Conn 6M (Naked lady) alto saxophone using the 3D printed model and the Yamaha mouthpiece playing a D$\flat_3$ (Figure 9) and D$\flat_5$ (Figure 10).

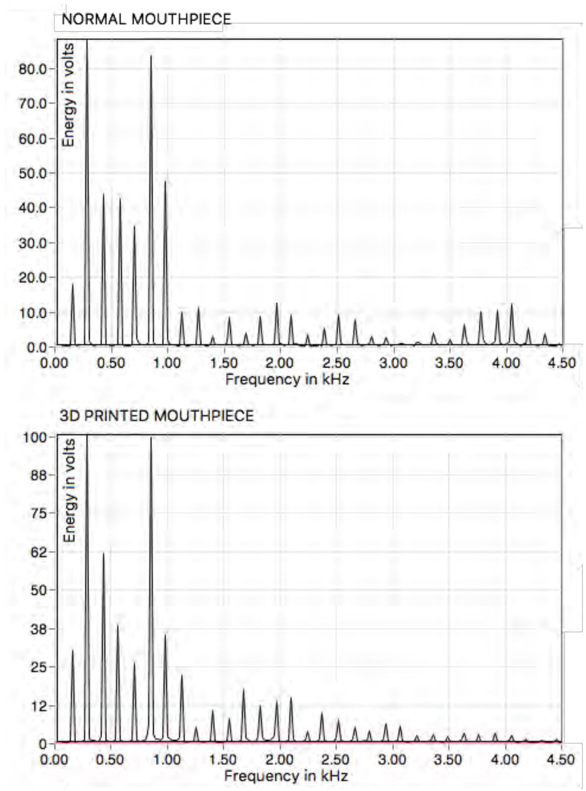

Figure 9. Overtones found in beginner Yamaha and 3D printed mouthpieces playing D$\flat_3$

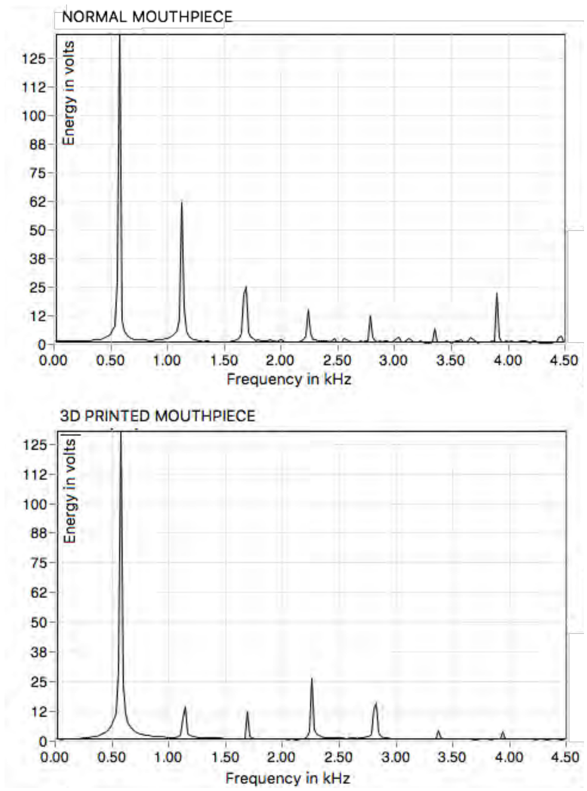

Figure 10. Overtones found in beginner Yamaha and 3D printed mouthpieces playing D$\flat_5$

5. EVALUATION AND LIMITATIONS

Up to this point, the mouthpiece design together with the barometric sensor has been successful. Nevertheless, the project has faced some problems such as poor 3D printing and sensor failure due to moisture.

Achieving a good printing quality can be difficult and it does not only rely on the printer: other factors such as material and, most importantly, 3D model design matter. The resolution at which some 3D printers can print can make it very difficult to print fine details such as the 1mm radius opening of the alternate air conduit. On the first printing attempt, this section of the conduit was completely blocked. To fix this problem it was necessary to do a manual perforation. The texture achieved by the printer was somewhat rough. The major problem with this texture is the fact that it could produce air leaks in between the mouthpiece and the lips of the performer, which not only can be uncomfortable for the instrumentalists but could also make the sound production more difficult. The 3D printed model texture was removed by sanding carefully and adding a coat of bee wax. The wax not only helped smoothing the surface but also gave the mouthpiece a more organic feeling, but most importantly helps reduce any disturbance of the air flow in the interior of the mouthpiece. This coating will eventually wear off, but the mouthpiece can easily be re-coated if necessary.

The preliminary results show a consistency of playing throughout the range of the instrument with a relative ease of sound control. Even though the beak is slightly thicker than the beak on a conventional mouthpiece, according to the 3 performers surveyed, it does not seem to be uncomfortable or to pose any issues for an experienced performer. More tests are needed to assess the repercussions that using this mouthpiece has on tone quality and harmonic content. Further printing attempts will consider these results, as well as the possible differences caused by printing the model with different materials and printing techniques.

The construction of the barometric sensor permits its use despite the presence of moisture. However, the breakout GY68 fails as soon as moisture is in contact with its components as the design does not feature a protective casing. The first tests proved that, after a few minutes of playing, moisture from breathing and saliva make the system fail. To correct this issue, silicone was applied over the entire surface of the breakout and edges of the sensor, leaving the front face of the sensor uncovered to allow the air to reach the internal components of the sensor. Three possible improvements will be explored in the future. The first one will be to attempt a more precise design in which the back opening of the conduit fits perfectly with the sensor face such that no air, moisture or saliva can escape to the breakout components. This solution would be ideal because it would make replacement of the sensor an easy task of pulling out the breakout and pushing in a new one, but it can be very difficult as it depends on the quality of the printing and each new model would be slightly different. A second solution is to use a 3D printer capable of mixing two materials in a model and redesign the model in a way that the back opening of the conduit features a silicone material that can press against the sensor in such way that it prevents moisture ingress. The third solution, and possibly the easiest to achieve, is to also print a silicone casing for the breakout which could be placed on the breakout before it is set into the mouthpiece; if the sensor failed at some point it would be easily replaceable by a new sensor utilizing the same silicone casing.

6. CONCLUSIONS AND FUTURE WORK

The project has been successful so far, achieving accuracy greater than anticipated. Although it may need to be further developed, the mouthpiece is at a stage where it can be used to perform and to offer information about the performance. The system has the potential to add a new feature to control live electronics: it can not only detect the air blowing into the mouthpiece, but also is capable of detecting air suction (represented as negative values under the baseline value set on calibration).

This mouthpiece can be used in various applications. The main purpose in the development of this mouthpiece is to use it as a tool to gather data that will be used in performance practices as part of the development of a hypersaxophone. More mouthpieces based on the same idea and design will be produced to fit different instruments of the saxophone family. Changes in the design will explore the tone quality production by changing the characteristics of the baffle, bore, chamber, etc. The data collected from the pressure sensor will be used in conjunction with other sensors to control live electronics and to alter the acoustics of the instrument itself.

A new software to gather information from the data will be created to make the study of performance more effective, so that the project can be used for pedagogical purposes. It will also feature a reed with an integrated sensor to further investigate the relationship between the tongue and air pressure, and the effects that controlling them has on performance.

The use of 3D printed tools combined with the new generation of highly accurate sensors holds promise for further developments, considering the wide variety of materials that can be used to print the models. The ease of manipulation of these models offers a fast and accurate way of prototyping, developing and creating final products that will enhance our interaction with musical instruments, allowing performers and composers to expand and realize their creative ideas beyond the current limits of instrumental techniques.

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RIP & TEAR: DECONSTRUCTING THE TECHNOLOGICAL AND MUSICAL COMPOSITION OF MICK GORDON'S SCORE FOR *DOOM* (2016)

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ABSTRACT

The earliest mainstream examples of the first-person shooter game can be traced to the early to mid 1990s, during which one company above most others cultivated a genre that continues to dominant the global video games market. id Software was founded by John Carmack and John Romero, and of all their video games it is perhaps the 1993 *DOOM* that has been most influential and celebrated. Advancements in technological game development and creativity afforded *DOOM* exhilarating gameplay, killing monstrous enemies, spurred on by a synthesized, metal-infused soundtrack by Bobby Prince. The 2016 reboot of the serious, similarly titled *DOOM*, had one of the strongest legacies to live up to in the gaming world. To both respect the series' lineage and give this new game a distinguishing identity, composer Mick Gordon developed unique technical and musical processes based on a philosophy of energy passing through objects, and so doing, corrupt them.

1. INTRODUCTION

This Alongside titles *Wolfenstien 3D* (id Software, 1992) and *Quake* (id Software, 1996), *DOOM* (id Software, 1993) is arguably one of history's most influential computer games. The 3D graphics, game engine and in-game assets were all causal factors in the popularity of this science fiction/horror game. Core gameplay, an exhilarating combination of linear level exploration and the dispatching of numerous enemies using a minacious array of weaponry, largely defined the first-person shooter genre. An ambient metal soundtrack composed by Robert C. Prince III (Bobby Prince) accompanied gameplay in original versions of the game, taking inspiration from bands including Metallica and Slayer. Subsequent to related sequel and expansion games, the series' original developer company recently released *DOOM* (id Software, 2016), with Australian composer Mick Gordon composing the score. Gordon's music dances nimbly upon a line dividing originality befitting this reboot of the franchise, and homage paid to the original game's midi soundtrack.

This was achieved through a number of experimental, procedural, musical and technical processes. Motivic content such as distinctive electric guitar riffs from the 1993 game soundtrack were reconstructed and transposed down onto a Schecter nine-string guitar. The ominously guttural melody produced was altered with effects, a process that was ultimately a cornerstone of the score's aesthetic. Gordon stripped his music to its fundamental sine wave and noise forms, and pulsed rhythmic excerpts of this sound through vast arrays of analogue equipment. Eschewing the traditional effect processing capabilities of vintage guitar effects pedals and reel-to-reel tape machines, Gordon unconventionally used the circuits within this equipment to corrupt the pure sine waves and noise. Ricocheting electrons transfigured the sonic matter, and Gordon harnessed the capturing of this energy to imbue his musical phrases with literal charge. A similarly explorative process was undertaken in using a Soviet-era Polivoks synthesizer, labeled in Russian, made all the more experimentally nuanced, as Gordon does not speak this language. These sounds were combined with dark synth-rock rhythm section parts and numerous metallic, electronic and 'other worldly' sound effects to suit *DOOM*'s in-game environment.

The narrative does not explicitly expound a post-human paradigm, however the two settings of gameplay are a research centre on the planet Mars and a seemingly secularist depiction of hell. These are both distinctly chaotic locales, devoid of genuine humanity but replete with monsters, and as a non-diegetic musical accompaniment to play the score reflects the abstract-cum-dystopian visual elements and themes. Gameplay can swiftly evolve such that the player may need to engage in close-quarter combat against limited opponent numbers, thence rapidly adapt to face oncoming waves of enemies in vast areas. The score reacts dynamically to such changes, altering components such as instrumentation and theme in real-time, based on player actions. In so doing, a musical intelligence is presented that at any one time may provide the player with both a substantiated diegesis, and individualised soundtrack experience. It is the singular technical construction and musical composition, broader narratological links and gameplay experiences of Gordon's score for *DOOM* that this paper seeks to elucidate.

2. THE FIRST-PERSON SHOOTER

By the early to mid 1990's almost a quarter of US households possessed a personal computers (PC), drawing millions of consumers to a platform experiencing a metamorphosis from the esoteric to the commercial (Kline, Dyer-Witheford and De Peuter 2003). Unsurprisingly, a wave of action games (and other genres) similarly saw commercial success during the same period. Garrelts (2005, p. 3) summarises that "as digital games have become more technologically advanced, the possibilities for interaction within the world of the game have also exponentially increased." As crucial as technological innovation was and remains to the gaming industry,[1] it is the exhilarating gameplay experiences afforded by this innovation that propelled PC gaming.

Texas company id Software was an active digital games producer of this era, defining the first-person shooter (FPS) game, with *Wolfenstein 3D* (id Software 1992) the first of many (Egenfeldt-Nielson, Smith and Tosca 2008). *Wolfenstein* portrayed a gameworld of a freely navigable castle environment, with structured pathways in which to exterminate numerous enemies. Key to the groundbreaking realism of gameplay was the first-person perspective, exploiting parallax-motion and graphics to place the player in the virtual shoes of the protagonist (Kline, Dyer-Witheford and De Peuter 2003). This design trope is fundamental to FPS games, in which the player will typically see no more than their character's hands or weapons (Grimshaw 2007). Other FPS games such as *Quake* (id Software 1996) and *Duke Nukem 3D* (GT Interactive 1996) further developed and popularised the genre, however it is the original 1993 *DOOM* (id Software 1993) that this paper takes as its focus.

3. *DOOM*, SOUND AND MUSIC IN FPS GAMES

Kline, Dyer-Witheford and De Peuter (2003, pp. 143-144) claim, "*Doom* was the game that blasted hard-core computer gaining to commercial success" and that it "it lived up to its title's apocalyptic overtones." The player controlled an unnamed space marine protagonist traversing several interstellar installations owned and operated by the fictional Union Aerospace Corporation (UAC). Through a deterioration of defense systems and protective forces, the player was compelled to battle and overcome an onslaught of demonic enemies through a number of game levels. John Romero's graphic design, and John Carmack's 'Doom engine' (game engine), the creators of id Software, produced a compelling experience of interactive entertainment, simultaneously peaking in both technological sophistication and violence.

A first-person perspective was fundamental to the design and popularity of the game, and to that end Romero has stated that the protagonist was given no name with the intent that the player felt that they were the space marine (Internet Archive 2002). The minacious array of weaponry at the player's disposal and up-front gore of dispatching monstrous enemies made the action and horror all the more immediate. Herzfeld (2013, p. 150) offers that the "joy of gaming is bound to the degree of plausibility in the dissolution of objective space and subjective perception," determining of *DOOM* that "the player sees and hears only what the avatar sees and hears." Key to this is concept is the perception of sound, on which Grimshaw (2007, p. 121) notes that, in such instances "the character and player are … one and the same." In union with bombastic firearm discharge sounds and animal groans providing the beast noises in the game, was a techno soundtrack infused with metal influences (Kushner 2003).

Robert C. Prince III (Bobby Prince) had previously worked with id Software and Apogee Software Ltd. (Kushner 2003), the publisher responsible for another landmark FPS game series, Duke Nukem. Inspired by bands such as Metallica, Slayer and Pantera (Polanco 2016), Prince's soundtrack for *DOOM* was part of a mid-1990's convergence of rock musicians and game studios. Similarly influential was the aggressive, industrial sound in the soundtrack for *Quake* was written by Nine Inch Nails frontman Trent Reznor (Mernagh 2000). These soundtracks were a harbinger for successful collaborations soon thereafter, such as *Wipeout XL* (Psygnosis 1996) featuring Daft Punk, Prodigy and the Chemical Brothers (Collins 2008), *Big Air* (Accolade 1999) featuring Blink 182, Diesel Boy and Limp (Mernagh 2002), and tie-in fighting game *Wu-Tang: Shaolin Style* (Activision 1999). A series of sequels, updated versions and expansions and have been released in the DOOM series, but it wasn't until a long running series of creative and corporate hurdles had been navigated that a genuine reboot of the series could be created (Hurley 2015).

4. *DOOM* REBOOT

Munday (2007, p. 51) describes that "[s]ince the mid-1990s, the improved memory capacity and increased processor speeds of game consoles have freed video-game composers from the technological constraints which gave the work of their predecessors such an identifiable aesthetic." This is true, however while technological constraints are comparatively alleviated, the expectations of legacy, popularity and icon-status pervade reincarnations of old universes. Award winning Australian composer Mick Gordon was chosen to compose the main score and musical elements for the franchise reboot game, having previously worked on titles such as *Need for Speed: Shift* (Electronic Arts 2009) and *Killer Instinct* (Microsoft Studios 2013). In Gordon's (2017, n.p.) own words, "modern *DOOM* is nothing but a tribute to 90s game design. Indeed, the 2016 game ultimately retained fast-paced gameplay, an expansive but linear level system and multiplayer modes in echo of its predecessor. As described by executive prouder Marty Stratton and quoted by Brinbaum (2015, n.p.), the fundamental narrative elements of *DOOM*,

[1] A contemporary example would be the introduction of Intel's Pentium computer chips.

"badass demons, big effing guns and moving really, really fast," remain consistent. It is a recapitulation of the most celebrated elements of the original game, with a story drawing on previous titles, but nonetheless original. Gordon embarked on composing the score wishing to respect the strong legacy of the series, while imbuing the project with its own unique musical character (GDC 2017).

5. DOOM – CORRUPTIVE ENERGY

From very preliminary stages Gordon's creative approach to composing the *DOOM* soundtrack was influenced by other elements of the (developing) gameworld, as well as more formalised guidelines. The initial music design document stipulated that guitars should not be used in the score, opting instead for synthesizers as a musical basis (GDC 2017). Gordon's initial act was to create a rhythmically recursive sub sine wave part. As a foundation upon which other elements could be based this action made sense, however the low pulsing required accompanying higher frequencies to delineate rhythm.

To this sine wave Gordon added white noise. A prima facie appraisal this choice of sound component could result in an estimation of banality; an axiomatic nod to common storytelling conceit of using abstruse sonic entities within the horror genre, as discussed below. While this was likely a factor in Gordon's creative thought process it was the implementation method of white noise that gives the *DOOM* score its character, not simply the inclusion of it. The white noise sound was turned on and off at a rate that mirrored the frequency of the sub sine wave underneath it. The sub was 'ringing' (bounces per second) at approximately 36.7-Hz in this case, and in alternating the white noise at the same rate Gordon essentially executed ring modulation at the audio frequency. The two parts were audible when combined, and by feeding this signal through a distortion process, extemporal harmonics were created. The result was sonically and aesthetically intriguing, however directives from id Software personnel compelled further investigation.

In studying design paraphernalia such as concept art, Gordon further established a broader electronic music palette that would suit the macabre visuals of *DOOM*'s settings. A specific visual component within the game's concept art of a recurring motif of stalactite rock formations resonated with Gordon. These massive geographical structures comprised two or three solid pieces of rock floating in mid-air, with crimson electrostatic discharges flickering between the compartmentalised pieces. The effect was an augmented stalactite, broken, with each piece held together by a lightening-like energy of unknown but presumably perverted nature. This visual depiction of energy pulsing through objects and becoming corrupted manifested in Gordon's conceptualisation of the composition process, seeking to answer what this energy might sound like (Gordon 2016b). The result was the pulsing of sine waves, described by Gordon (2017, n.p.) as the "most pure representation of what sound can be", through analogue equipment, not to utilise their intended effects processor elements, but rather "using the circuits of the equipment to corrupt the pure sine waves and noise" (Gordon 2016b). This became foundational to the construct of the score, and eventually epitomised the entire game's narrative. It highlights Munday's (2007, p, 62) articulation of using "music to provide stylistic cues to aid the comprehension of [games'] particular setting and narrative genre." Gordon's concept however seemingly transcends a symbiotic relationship of sound duplicating and enriching visual information, as conceived by Chion (1994) and as compared with video games by Munday (2007). It is perhaps more accurately surmised by Summers' (2016, p. 59) aphorised calculation that "music in games often obviously deploys strategically chosen musical signifiers in order to finish the games' fictional construct." Summers' also draws on Juul's 'cueing' nomenclature (Juul 2005) in stating that music 'cues' the player to understand the universe of the game (Summers 2016), thereby equating the game music to the game narrative as a whole.

In the plot of *DOOM* the (reprised) UAC seeks to hoard and monopolise an immensely powerful form of energy, ostensibly to remedy a power shortage but clearly to exploit power; that is, good versus evil. This archetypal narrative dichotomy pervades diegeses, liturgical teachings and ethical discussions, with video games just another, comparatively recent, format for story telling, as expressed by Murray (1997) in Kerr (2006, p. 24). Naturally, there is also a 'hero' component to the plot of *DOOM*. The player-controlled protagonist is forced by to, as Zehnder and Lipscomb (2006, p. 250) articulate, "undergo a series of trails or difficulties, often involving a descent into hell (at least metaphorically)."[2] Absent however is the consequential resolution of returning to the ordinary world (Zehnder and Calvert 2004). Mover the game only partially adopts the classic Aristotelian model of narrative, dispensing with the more romantically satisfying notion of unwinding (denouement), but, as in a song comprised of so any dominant seventh chords,[3] a constant succession of rising action (desis) and climax (peripeteia) (Zehnder and Calvert 2006). What is distinctive and consistent in *DOOM* is the notion of flowing or being pushed through something, like a corporation imbuing machinery with corruptive energy, or floating rocks connected by lightening bolts pulsing through them. The game's quintessential FPS design allows the player various ways to navigate required objectives and their environment, but within a strictly linear overall narrative progression and level system (Calleja 2011). Even at this macro level, the concept of passing through could be applied to

[2] In the case of *DOOM*, this is a literal descent.

[3] A relevant example would be the jazz standard 'All of Me' by Gerald Marks and Seymour Simons.

the player's progression through what is essentially a number of walled tunnels (levels), facing corruptive elements therein.

6. THE *DOOM* INSTRUMENT

To bring this concept to bear musically, Gordon constructed a complex and sophisticated array of audio signal pathways and distortion controllers, through all of which a sine wave was fed. Figure 1 is a screenshot from Gordon's 2017 Game Developers Conference presentation (GDC 2017), and shows the signal branches and sonic pathways that the eventual array consisted of. As it demonstrates, a signal generated by a computer was split into four pathways, each of which thence went into a chain consisting varyingly of effects pedals, speakers and other equipment.

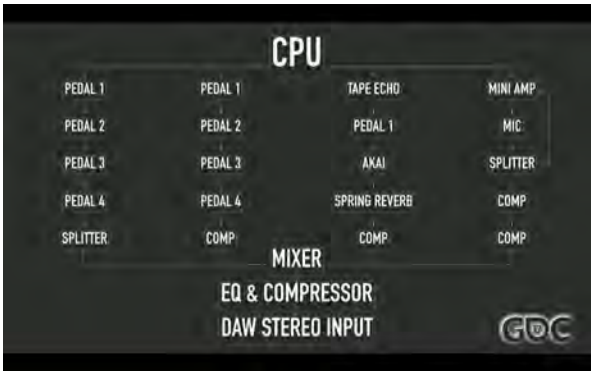

Figure 1. Gordon's '*DOOM* instrument' array.

The predominance of 'pedals' listed belies the true variation of the equipment. For example, within the first two pathway chains (left to right) resides a Retro Mechanical Labs 432k Distortion Box (focused on signal routing), a Metasonix KV-100 (tube distortion), two Geiger Counters (bit crusher), Dwarcraft Fuzz pedal, Metasonix TX-3, Mu-Tron Bi-Phase (ca. early 1970's phaser pedal) and a DOD phaser pedal (ca. 1970's), as well as the listed splitter and compressor. The vast opportunities presented for sound distortion and attenuation are compounded in the other two paths. The third pathway chain begins with a Watkins Copicat Tape Echo machine (ca. mid-1960's tape-reel compact repeat-echo machine and a Trogotronic valve distortion box (used more for compression features). An Akai reel-to-reel tape machine (ca. 1070's, fed approximately 40-dB over capacity and recorded back off the machine simultaneously), a Spring Reverb Tank (with a wet/dry control) and another compressor follows. The fourth pathway chain begins with a mini-amp (small speaker, again fed approximately 40-dB over capacity). This amplifier had a microphone recording its emitted sound, and a small portion of its own signal was sent back via a splitter. An intentional feedback loop was created, so small that when a sound emanated from the speaker, the feedback sound would be 'choked out'. The effect was a constant and smooth fluctuation between a distorted signal and feedback sound, which was thence fed into another two compressors. The split signals of all four pathways ran into a mixer for control purposes, then through equalization and compression, the latter of which was overclocked to approximately 20-dB. This was so that when the loud noises faded away, the compressor would open up and bring to the fore all of the various noise elements created by the pedals and equipment. This compressor had an attack set for approximately 30 milliseconds to produce a solid, punchy sound, with the release alternated depending on the tempo of the sound pulsing through it. Finally, this signal was fed into a digital audio workstation with stereo input for editing (GDC 2017).

There are obviously copious sound-control possibilities within such a vast network of effect pedals and machines, however other extemporaneous sounds were produced through experimentation. For instance, Gordon found that by playing consecutive intermittent F notes, an E, or a microtonal approximation thereof, would be created. This was not from conscious input by composer or computer, but generated by sources of ground hum within the setup, eerily reminiscent of John Williams' iconic shark motif (Burlingame 2012) in the score for *Jaws* (Spielberg 1975). Tonal harmonics were also created, as well as multiple layers of compressed distortion. These and any intended effects generated by the machinery remained true to Gordon's inspiration of a pure sine wave travelling through equipment, and in so doing becoming corrupted. So compelling was the tangible superlative modification of sound within this array that Gordon was led to "think about this as [his] *DOOM* instrument" (2017, n.p.). It became a predominant component of the *DOOM* score, producing multitudinous effects, distortions and contortions to sine waves whose only manipulation was initial amplitude and pitch.

The result was an audibly corrupted series of musical cues. By using the analogue equipment circuits to affect the sine sound instead of using digitally synthesized effects, there was a tangible grit and depth evident in the music. The ricocheting electrons transfigured the sonic matter, and Gordon harnessed the capturing of this energy to imbue the score with charge, both quixotically and practically. The extemporal electronic hums and metallic noises natively created by the *DOOM* instrument array compliment the abstract-cum-dystopian visual environments. Later stage equalization, mastering and transient processing remained a part of the process, creating balanced mixes with controlled dynamic ranges. It is because the sound was fed through amplifiers at decibel levels greater than the equipment was designed to handle however, that the music genuinely creates a sonic image of literally ripping and tearing sound apart.

7. MUSIC, ENVIRONMENT AND HOMAGE

The *DOOM* (Bartkowiak 2005) film based on the extant game series' universe was similarly based mostly on a future-set Mars, and depicted human citizens of a colony. The 2016 (video game) reboot of the series however showed little in the way of human inhabitants. Main non-player characters (NPC) such the facility director Samuel Hayden and scientist Olivia Pierce are cybernetic organisms, the UAC artificial intelligence named VEGA has no humanistic corporeality, and other identifiable humans are deceased and typically clad it full-body armour. The most prevalent depiction of human forms is perhaps the crimson floor piles of blood and loosely draped strings of internal organs, the sole remnants of eviscerated facility staff. The player is informed that humans have existed in the Mars facility until recently, meaning that the introduced paradigm is neither post-human nor post-apocalyptic, but rather one of dystopian massacre and peril. The two literal 'other worldly' environments of hell and the UAC Mars facility are overrun with monstrous creatures possessing the single ambition of extreme malevolence.

To sonically match the visual elements, Gordon maintained focus on the claustrophobic, aggressive, brutal, tactile and piercing experiences of gameplay, with the score aiming to "capture that complete lack of restraint" (Gordon 2016b). Again employing procedural and technical experimental methods, the composer turned to a 1980's Polivoks synthesizer to sonically match the visual elements. The analogue, duophonic instrument was manufactured in the Soviet Union, and as Gordon's was an original model it was labeled entirely in Russian, a language not spoken by the composer. Rather than a deterrent, this allowed for creative freedom when composing, with less focus on effect ratio measurement, and more on pure characteristic of sound. The onboard oscillators and filters of the Polivoks could provide desired sound of ambiguous origin and nature, and when combined with the '*DOOM* instrument' array exponentially increased Gordon's tools of creativity (ibid. n.p.). As briefly discussed above, the fiction of the gameworld is supported and enhanced by the game's soundtrack. Producing musical accompaniment to play that is convincingly copacetic as to give meaning to such an abstract gameworld presents challenges. Schell highlights the importance of using sound to convince the player of 'space' in a gameworld (2015), while Sweet determines the importance of musical themes establishing locations within a game (2014). Munday (2007, p. 53) similarly offers that in the case of video games "it is worth remembering that computer-generated environments make no natural sounds: hence the importance of music and sound effects to give them meaning." The initial directive from id Software was that guitar was not to be used in an attempt to distance the soundtrack from the generic. With a history as a guitarist however, and a strong sense of the affinity between guitars and the original *DOOM* soundtrack, Gordon developed the view that it was this very instrument that was missing from the soundtrack (GDC 2017).

Gordon once again changed typical composition processes to enable the production of interesting musical outcomes. In so doing, the composer paid homage to the most definitive and celebrated elements of the original *DOOM* soundtrack. Having convinced a case for increased guitar use, Gordon singled out the iconic 'E1M1 riff' found in the track 'At Doom's Gate', heard the during the 'E1M1: Hanger' level from the first *DOOM* game. Gordon has opined, "that original E1M1 riff is iconic, it is *DOOM*" (Gordon 2016a) but was not prepared to recapitulate it verbatim for the 2016 game. Instead, through a number of iterative stages, Gordon reorganised the original four notes of the E1M1 riff, creating a new riff reminiscent of E1M1 but possessing its own original construct.

Part of this construct included the transposition of this motivic content down onto a Schecter nine-string guitar, conjureing a depth and grit otherwise not possible. This process was itself inspired by audio engineer Sean Beavan's work with Marilyn Manson and Nine Inch Nails. Beavan would have guitar parts played up an octave at double the tempo, recorded to tape at 30 inches per second. The tape would then be slowed to 15 inches per second to produce unnatural qualities. This was replicated by Gordon, with the guitar signal pulsed through an additional preamp. Further distinguishing the distorted sound, the Morph audio editing plugin by zynaptiq was used to interpolate characteristics of one sound into another sound. Shrewdly, Gordon interpolated elements of the original *DOOM* game chainsaw sample into the guitar tone, thus imbuing the new riffs with a tone perpetually linked to the sonic identity of its predecessor. The resulting melody, ominous and guttural, was used in the track 'At Doom's Gate', sharing eponymous and musical links with the 1993 original track (GDC 2017). Phillips (2014, p. 149) has identified a main theme as serving "as a game's musical signature," and notes their ideal positioning to "help game players mentally organise the game world and emotionally interact with it" (ibid. p. 72). This importance was a substantive element in Gordon's creative process. As with much of the score, the new version of E1M1 also featured additional instrumentation in the form of dark synth-rock rhythm section parts (Machkovech 2016). This too was a carried-over influence of Prince's original midi soundtrack, and the metal-styled drums and bass parts encouraged the player to navigate the gameworld arena with increased vigor and excitement (GDC 2017). This one riff essentially exists as a microcosmic representation of Gordon's score nimbly dancing upon a line dividing originality befitting this reboot of the franchise, and deference to the original *DOOM* soundtrack.

8. DYNAMIC MUSIC AND SOUND EFFECTS ACCOMPANYING PLAY

As Collins (2008, p. 4) states, "nonlinearity is one of the primary distinctions between video games and the more linear world of film and television, in which the playback is typically fixed." Munday (2007, p. 62) similarly notes that "a significant amount of video-game narrative is not causally predetermined, because it is generated 'on the fly' by the actions of the player." Wall-to-wall music no longer features as prominently in modern FPSs (ibid. p. 53), unlike earlier examples in the genre such as *Goldeneye 007* (RARE, 1997), in which missions are accompanied by Graeme Norgate and Grant Korkhope's score referencing, but not re-creating (Summers 2016), that of the film on which its based.[4] The technical implementation of music in *DOOM* was largely executed by the audio development team of id Software, with Gordon supplying separate sections of music as Wwise[5] files. This separation process was in support of increased variation, with bars of music able to be rearranged and avoid looping track situations.

The music in *DOOM* is most susceptible to extemporaneous change during core gameplay level exploration. At times it is indexical, subdued and awaiting the player's activation of a cutscene, which in-turn cues an immediate and brief invasion of the game space by multiple enemies. The score reflects this increase in danger and required agility by switching to explicitly invasive and loud cues. Machkovech notes that these more 'brutal' arrangements of guitar and synthesizer riffs are noticeably triggered as gameplay changes from the player engaging close-quarter combat against limited opponent numbers, to rapidly facing oncoming waves of enemies (2016). This is a dynamic action as it is pursuant to the player's timing, but is a consistent part of the level design, and in this one instance the score performs a number of functions. It acts as a referential means of musical communication (Zehnder and Lipscomb 2006) by alerting the player to the changing state of play and their increased danger. It also fulfills the role of an emotional signifier (ibid.) by eliciting the excitement, anticipation and focus required of the player to successfully defeat the oncoming monstrous masses. Gordon cites this and one other example as the most complicated features for which the dynamic music system of *DOOM* was built (GDC 2017). The other example is the musical accompaniment to 'glory kills', a melee execution system whereby the player rushes to an injured enemy and triggers a short cut scene, just a few seconds in length, featuring the enemy's gruesome death. Depending on achievement settings glory kills in singular or successive forms may take differing amounts of time to complete, and such instances would ideally occur without abrupt interruption to the music. To mitigate this indeterminacy of length, Gordon and the audio development team chose to very briefly fade out the ongoing score during glory kills, and implemented what Gordon terms 'looping rises', which were based on a Shepard tone. By utilising the distinguishing elements Shepard (1964, p. 2346) describes as a "continuum of frequency and … perceived pitch," a tonal sound of seemingly infinite rising could accompany the player's action. This almost approximates an exampling of 'micky mousing', which Zehnder and Lipscomb (2006, p. 245) summarise as using music to comically emulate "the physiognomic structure of physical motion," as proposed in earlier work (Davies 1978). Similarly described by Lerner (2014), Whalen (2004), and Neumeyer and Buhler (2001), such actions require syncronised kineasthetic and audial components to achieve the desired effect. *DOOM*'s glory kills however comprise a number of 'finishing moves' by which the protagonist smashes, rips apart and mutilates enemies. If given a musical moniker rather than classed as a sound effect, the 'looping rises' would constitute a stinger, a musical punctuation (Zehnder and Lipscomb 2006) tied to the glory kill action.

So linked are the aberrative sound effects and musical cures in *DOOM* that it can become difficult to distinguish between the two. Munday (2007, p. 53) has gone as far as to suggest the argument that "sound effects have begun to supplant the environmental function hitherto assigned to music." Collins (2013, p. 3) cites film sound designer Walter's descriptor that "most sound effects … fall mid-way" between noise and music. Reznor's music for the depraved gameworld of *Quake* amalgamated sound effects, electronic atmospheres, ambient noises and music (Mernagh 2000). The commensurate relationship in the 2016 *DOOM* contrasts celebrated ambient soundtrack games such as *Silent Hill* (Konami 1999), described by Roberts (2014, p. 138) as using music "as a continuous atmospheric signifier of danger", and about which Whalen (2007, p. 76) has emphasised the use of static to convey musical "pitch modulation, rhythm and repetition." Elsewhere, Whalen (2004, n.p.) describes composer Akira Yamaoka's score as evolving to a "cacophonous ringing of metallic noises and atonal chaos," causing a conflation of music and ambient sound effect elements. The use of white noise in *DOOM* is a correlative example. This signal sound has proved particularly effective in the horror genre, so much so that it inspired both title and plot of *White Noise* (Sax 2005), and is still used in contemporary games such as *Resident Evil 7: Biohazard* (Capcom 2017). What distinguishes Gordon's soundtrack however is the use of white noise not to provide sustained pads of sonic ambiguity, but as a higher frequency articulation of the sub sine part.

The incorporation of 1993 *DOOM*'s chainsaw sound effect mentioned above goes to more intertextual

[4] It should be noted that while music plays throughout each game level, once objectives had been achieved toward the end of levels a briefer, more intense version of the previously looped theme is cued.

[5] One of a number of 'middleware' software packages used by composers that allow better communication between a game engine and digital audio workstation.

narrative considerations, while completely new sound effects created for the 2016 series reboot required different attention. One such example, pervasive to sound design in car racing games (Donnelly 2014), is the implementation of sound effects and music within the single frequency spectrum. An example of this in *DOOM* is a 'chain gun', which is capable of such a high rate of fire that when the trigger is depressed and held, the discharged rounds result in a sustained sound pressure level, and thus, a tone. A firearm's acoustic resonance spectroscopy measurement (Haag 2002) can therefore impact upon the composition of music. This in-game firearm sound effect was designed to rest at a low concert D note, aligning with the score, which was strategically composed with a D root note, thereby avoiding a clash of frequencies (GDC 2017). These examples highlight the design and implementing the music (and sound effects) of *DOOM* to accommodate changing states of play. The music provides a musical intelligence that at any one time may provide the player with both a substantiated diegesis, and individualised soundtrack experience.

9. CONCLUSION

This paper has sought to elucidate the singular technical construction and musical composition of the score for *DOOM*. Through detailed descriptions of Gordon's inspired use of analogue equipment, it has demonstrated the 'corruption of sound' philosophy behind much of the game's music. By exploring links between audial and visual elements in games, and applying game design practices, connections between the music and overall game narrative are presented. In addition to musically portraying the highly abstract gameworlds of *DOOM*, plot themes are represented by music design, and in-game experiences are accentuated and underscored by the score style. With death and violence the predominant (and existentialist) indicators on a baron planet Mars and seemingly secularist depiction of hell, Gordon's score discourages nihilistic wallowing in favour of merciless rampaging. This encapsulates the celebrated gameplay of the original *DOOM* game, evidencing deliberate narratological links within the series. Players receive sonic information from the 360 degrees of their gameworld environment (Morris 2002), perhaps particularly so in FPS games (Munday 2007). As a full audial component of gameplay, the score and sound effects for *DOOM* are so designed, providing clues relating to changing states of play, and adapting to the player's extemporal actions. Summers (2016, p. 77) offers the summation that "[m]usic, through texturing the game, represents a core part of how the game (its characters, worlds and actions) are understood by players. Music does not simply 'underscore' games, but it is part and parcel of the actions in, and worlds of, games." Such a statement is germane to the description of *DOOM*, insofar as the music giving the game as much of its character as the plot and environments. It is concluded here that Gordon's composition is a truly unique game score, and like its 1993 predecessor, is patently *DOOM*.

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INRUSH :: PROTO-TYPING A QUEER METHODOLOGY FOR NETWORKED PERFORMANCE

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ABSTRACT

Inrush is a collection of java classes and max patches, proto-typed by Dan Thorpe between 2014-2017 to explore the potential of queer-theory methodologies in reactive performances. The result, and what this paper reports on, is a toolbox for composing mixed graphic and traditional notation works, synchronised over network, and drawn on the fly using OSC messages timed through input either from analysis of a dataset, a "score performer", or a mixture of the two. The first focus of this paper is on the theoretical motivations of such an approach, and two case-studies of how Dan Thorpe has used this approach in two reactive works: firstly, a more in-depth study of his work *A20* (for piano, projection, generated traditional notation scrolling score and electronics), and a report on his work in progress *scène* (a double concertino for flute & electronics with mixed ensemble, electronics, and rehearsal-realised mixed notation score), which will be presented at this conference.

1. INTRODUCTION

Inrush is a collection of java classes and max patches I prototyped from 2014-2017. I began writing software with the aim of exploring reactive approaches to notation and performances that acknowledged and embraced performer body autonomy, explored ways of sensing bodies and musical gesture that celebrated ambivalence and error, and struck a middle ground between fixed and unfixed/composed and improvised. The result, and what this paper reports on, is a toolbox for composing mixed graphic and traditional notation works, synchronised over network, and drawn on the fly using OSC messages timed through input either from analysis of a dataset, a "score performer", or a mixture of the two.

This paper will focus on the theoretical motivations of such an approach, and two case-studies of how I have used this approach in two reactive works: firstly, a more in-depth study of my work *A20* (for piano, projection, generated traditional notation scrolling score and electronics), and a report on my work in progress *scène* (a double concertino for flute & electronics with mixed ensemble, electronics, and rehearsal-realised mixed notation score), which will be presented at this conference.

2. THEORETICAL MOTIVATIONS

2.1. Queering I/O

In his 2002 paper *Interactivity, where to from here?*, Paine raises an important question of semantics: why do we talk about systems that offer no possibilities beyond those pre-determined by their designer as *interactive?* These systems, as Paine terms it, are *reactive*: responding to performer choices but with no level of cognition. Indeed, most systems we currently term as interactive are re-categorised by this definition as reactive (Bongers, 2000).

On the face of it, this difference is purely semantic, but a technical language that indicates falsely that users have the power to shape their relationship with technology reflects more broadly on culture that insists on participation in ubiquitous institutions without any real power in their shaping or articulation. There is a queer necessity to imagine and enact possible futures outside of these limits, to explore the not-here-yet of which queerness offers us a glimpse. This project is, therefore, the beginning of a personal, queer resistance to this technological and social paradigm: an experiment in a reactivity that is by design editable, extensible and manipulable by users with even basic technological literacies. An experiment in the redistribution of the power of decision making, structuring and code-level control from the system designer and explore new relationships between designer and users and the documentation of methodologies to do so.

This desire for negotiability, dispersion of power and extensibility in reactive design and in performance comes from a radical queer politics of utopianism, of queerness as a horizon. Much of 21st century queer politics has been characterised, thus far, as one of pragmatic institutional integration — of straightening. In her criticism of Andrew Sullivan's emblematic neoliberal gay text *Virtually Normal*, Duggan offers a withering insight into the state of '*The New World Order! Coming soon to a mainstream near you*':

> ''equality' becomes narrow, formal access to a few conservatizing institutions, 'freedom' becomes impunity for bigotry and vast

> inequalities in commercial life and civil society, the 'right to privacy' becomes domestic confinement, and democratic politics itself becomes something to be escaped.' (Duggan 2002, 191)

There has been an '*erosion of the gay and lesbian political imagination*' if we find our mainstream politics fleeing from the radically re-configured futurism queerness offers: why do we talk about means of existence that offer no possibilities beyond those pre-determined by the dominating voices of the already-in-power as advances in our rights? (Muñoz 2009, 21) Indeed, a queerness that is '*not here yet*' is the queerness that drives my practice, a desire to '*strive, in the face of the here and now's totalising rendering of reality, to think and feel a then and there*' (Muñoz 2009, 1 — Muñoz's Emphasis)— a then and there in which queer bodies and narratives, regardless of how well they fit the dominant institutional narratives of the here and now, are taken into account. There is a need to develop escape routes from uncritical reflection and reification of the institutional control of bodies, in queer politics and in queer art practice, and that is the primary goal of this project. This will be explored in reactive composition: both through an investigation of how it can reproduce politics of control, and the development of queer methodologies to construct reactive systems with radical queer politics at their centre.

2.2. Power, Interaction, and Composition.

There is a necessity to begin the discussion of this project, therefore, by establishing how the power relations of interaction design and western compositional practice can be critically recontextualised in the context of queer understandings of power (Foucault 1972, 66). Firstly, it is necessary to interrogate a common site where the power relationships of reactive systems and music surface. This is explored in the techniques of mass-participation and feedback employed in marketing, both as a phenomenon that has shaped the design of reactive software systems, as discussed by Galloway and Thacker (2007), and how it has shaped the production and recording of music, as discussed by Attali (1985). Secondly, we will explore how the institutional sites responsible for these traceable effects delimit who is allowed to speak and what can be spoken. We will also address how this influences the construction of conceptual approaches to interaction and performance, and how the themes and theories of the discourses that emerge from this produce strategies of control. Finally, we will discuss how this project aims to develop new methodologies through expanding cracks in points of incompatibility within discourses of western compositional practice and interaction.

It is important to note that what is being analysed here are certain regularities of the discourses around interaction and composition (Foucault 1972, 72). This study does not aim to find or investigate the origins and genesis of these fields, but rather to try and account for and interrogate the networks of force relations that form these fields in an attempt to inform a queer approach to these fields.

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There are two primary models we can understand as structuring interactions between a system/its design and users. The first is what both Galloway and Thacker (2007, 122) and Paine (2002, 296) refer to as *interaction*. Interactive technologies form entire systems of distributed peers, in various groupings, in which each peer is able to physically affect the other. In interaction there is the necessity for reciprocal action and mutual experience, Paine suggests artificial intelligence as a means of achieving this in the context of human-computer interaction (Paine 2002, p 296). Developing earlier, but also continuing to develop in parallel with interaction is a process Galloway and Thacker refer to as *feedback* and what Paine describes as *reactive* work. For the purposes of this paper, we will understand *feedback* as a process undertaken by systems and their designers, and *reactivity* as a property of systems consisting of a monodirectional informatic loop that enables feedback, from producer/designer to consumer/user and back to producer/designer via the market, research, polling, data gathering, sensing of bodies, and so on. This informatic loop supplies a flow of information from the user to the monitoring system — designer, institutional, technological or otherwise — that drives decision-making based on the criteria selected to asses that information (Galloway and Thacker 2007, 122). As Galloway and Thacker (2007, 123) comment, in reactive systems 'the audience is structurally unable to achieve a symmetrical relationship of communication with the apparatus (no matter how loudly one yells back at the screen)'. Feedback is observed in the context of music through the mechanisms of creating, selling and recording. As Attali notes, profit under 20th century capitalism is found in the creation of the most perfect mould for repetition. In this sense, the creation of notation and recordings for repeated performance and playback can be understood as primarily being structured through a feedback process through the mechanisms of the market (Attali 1985, 118 and 128).

There are several key observations that can be made from these surface realities, however the most important for this project is that reactive systems rely on technologies of surveillance and data collection. These technologies inevitably generalise populations while also paying close attention to the detail of individual bodies through the lens of that generalisation. The process of feedback not only refines the product, but the institutional view of those consuming; certainly from a queer perspective there is an element of fear in being recognized as an outlier from this dataset by potentially oppressive technologies of the state. A methodology of continually emerging importance, biometrics, is a method of power-knowledge that privileges feature extraction for the expansion of a data-set over a negotiated, self-identified engagement with a system. Indeed, the use of biology as a state method for identification and control of social sub-categories (class, sexuality, gender, etc.) as the basis for an understanding of human relations has been part of western discourse from Malthus (1798) and Darwin (1859) to Foucault (2010). This is echoed in the way recording has shaped the expectations of replicability in performance and composition. The performer's body is something to be trained to meet the standards of a pre-set ideal, the composer's work to expected to either enforce or increase these standards. Individual input is limited to a narrow field of interpretative choices within the scope of tradition and the composer's stated preferences.

Queer experience understands the necessity to intervene in the reification of these strategies of control and identification of the non-standard across discursive boundaries as a matter of life and death. There is an urgency to interrogating these practices, but also reconstruct existing practices with radically altered priorities and power relations. To do so, we need to examine from where control emanates in the existing structure. Galloway and Thacker argue that power in networks lies somewhere between the hierarchical powers enforced by the nation-state and those at the level of protocol: the laws of encoding, decoding and transmission that govern the functioning of the non-geographically bound (but by no means apolitical) networks. It is a result of a wide array of power relations and institutional prerogatives that reactive systems and scores present a narrow range of responses as the power to shape and negotiate your relationship to a system in a power relationship that is fundamentally asymmetric. This dramatically influences the construction of conceptual approaches to making software and to making art. The most obviously traceable surface effect in contemporary western compositional practice is the tensions raised in graphic scoring practice between the acts of composition and performance. Hope (2011) elegantly explores this in the context of programmers (who she earlier compares to performers [p.56]); acknowledging the compositional potential in those who realise conceptual work unfixes composition from the limits of a linear score. In interaction design, it is best epitomised in the aforementioned terminological tension between reactive and interactive. "The tension in both of these cases are uncomfortable truths of ingrained power relations. The notion of the "genius narrative" thrives on the presence of the all-knowing composer: there is no room for leaving open, or, worse still, *needing* input. One cannot describe one's system as *reactive* because it acknowledges the uncomfortable realities of participation in institutional powers under capitalism. Inevitably, these structures are replicated and formulate into strategies of control that enforce these underlying power relations.

The intervention into this that queer theory offers can shift these distinctions from binaries into something far hazier. Questions of a 'line' at which composition becomes performance or improvisation become irrelevant when decoupled from the power dynamics that demanded that distinction, and certainly reactive work that is decoupled from the power dynamics implied by a certain mode of designer/user relations can question what it means to interact with a system. Along with access to the code, and the intrinsic input my graphic notation suggests, this project explores the critical leverage of protocol to achieve this goal, channelling and interpreting input in a way that interrogates the social construction of interaction. Protocol acts on the *edges*, the connections that exist between *nodes* in a network. Following this line of thinking, composition takes on its more material definition, addressing the make-up of a reactive performance on the level of substrate: the 'wiring' — physical, software and cultural — between nodes. If notation is usually a surface effect of career spanning process of feedback, in this project it is both a critical stand-in for this tradition and, in the ways the reactive systems in this project disrupt and make this tradition unstable, a surface effect of the re-negotiated power relations operating on the level of protocol. This forms a critical engagement with the hierarchical power that enforces a model of the score as an ineluctable document of compositional genius, and with an assumption of the ability to record and repeat as a fundamental priority of composition. If an observable response from a system is usually a surface effect of a series of choices made exclusively by a designer designed to respond to measured and constant surveillance of a user, in this project it blurs perceptions of whether it was either designed, performed, or even a response in the first place. This forms a critical engagement with the hierarchical power that enforces a model of the designer as the only decision maker, and with an assumption that surveillance is fundamental to reactive systems.

The interactive and graphic scores that act as a technological backbone for the work in this project are a site of convergence between the theoretical background of this research and the strategies mobilised in my work to address the themes and theories unearthed in that process. They mobilise a critical illegibility that doubly reflects on the illegibility of queer bodies in cis-straight frames of reference and on the opacity of the technology on which we rely (Menkman 2011, 11). The vastness of potentiality of the network structure and the queer body, its illegibility and free-floating definition, make it impossible to exist in any other state of understanding.

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This project exists at the points of incompatibility in these discourses, between reactive and interactive, and between composition and performance. We have seen how queer theory offers critical insight into the power structures of interaction and composition, and this project mobilises this to further widen and interrogate these cracks in discourses. The result is methodologies of co-creation, participation and sensing bodies that aim to reconstruct low-level and far reaching power relations in interaction. This context leaves us with rich terms for a practice-lead investigation into a queer approach to reactive composition, and for the development of software that enables different approaches to performance and composition that reflects these values.

3. THE SOFTWARE

Inrush is a continuation of a trend in my practice more broadly to explore openness and negotiability by performers/users. There was a conscious choice to use well documented, industry standard software in the hope that performers would either be more familiar with or easily able to familiarise themselves with the basic coding skills required to interact with the structural elements of the pieces. I decided to work with Max and Processing, which both also have their own Integrated Development Environments (IDEs), because they fulfil these requirements and are also both very stable and well-established languages.

A20 and *Scène* were chosen as case studies for this paper because they represent two approaches to score generation — algorithmic and through performance — but like all of my practice have a critical drive that I very much identify with my understanding of queerness. Even in *scène*, where the queerness is less opaque, as a composer it is important to me that my desire for negotiation and autonomy is something that comes directly from a queer experience of the body and the body's place in the world. While this is not an exclusively queer idea, for me it is the framing that is most intuitive and allows me to engage more fully in forming a criticism of how heteronormativity limits bodies in my work and in life.

3.1. General Notes

The score drawing software developed for what I am now calling *Inrush* was designed to draw and control the drawing of traditional and graphic notation using a combination of Open Sound Control (OSC) messages and pre-programmed phrases and controls. Written in Processing, a flexible and user-friendly programming language designed to teach coding skills to those in the visual arts, the code is highly legible and extensible by end users (Reas and Fry 2006). The software accepts OSC messages formatted similarly to standard MIDI for note duration, pitch and velocity, and custom messages for changing note scroll speed, the number of and OSC addressing of staves, player colours, and for drawing lines and curves.

The Max/MSP patches developed for the three pieces in this research are likewise extensible and flexible to suit end user needs. I've focussed on designing patches that are modular, but still show clear signal flow and design logic so they can be pulled apart and re-constructed by end-users as necessary, in the hope that this transparency will be encouraged more broadly in designing patches for performance.

3.2. A20

A20 is a generative piece for piano, projection, generative score and electronics. It's an exploration of outer-suburbia, the centre of Australia, queerness and constant motion. An audience member once jokingly remarked (thinking I was out of earshot) that the projection in this piece is a bit "Mad Max"; amusingly, it's precisely the inability to be identified and vastness of inner-Australia that drove me to make this piece, and to document my (semi-regular) drives between Adelaide and Sydney. There is something about the potentiality of being on the road in between two far-apart places that unsettles our definitional systems – if you're not in Adelaide or Sydney where are you? If you're not gay or straight what are you? The places in between exist, of course, but in a blurry infinity of choices; of course, between Adelaide and Sydney there are an infinity of blurred, queer spaces too, with illegible and obscured identities and desires.

Maybe the problem is the geography – pre-mapped positionalities of identity, desire and place. How can you perform your way out of the erasure implicit in this way of mapping? Massumi suggests that we get caught in cultural gridlocks like this because our ways of understanding bodies subtract movement from the equation. Even bodies that change position on the cultural grid are defined by their start and end points, the notion of a body in transition is lost to an understanding that privileges the convenience of pre-defined socio-cultural destinations (Massumi 2002, 3–5). *A20* uses this cultural stasis as an interactive framework, deliberately employing the erasure of blanket processing and exploring this to a point of hypertrophy through constant feedback in (potentially endurance) performance. The footage that is only identifiable as *passing through*, not able to be pinned down more than vaguely within a physical or definitional geography beyond this.

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The primary outcomes of this piece, in terms of moving towards establishing a queer reactive compositional practice, are related to exploring the power relationships taken for granted in the performance of notated music. The act of being watched and measured by technology is one that has broad social context. Blas writes about this in the context of 'Fag Face Mask', his work that addresses a Tufts University study towards biometric means of detecting gay faces, arguing darkness and illegibility are a queer strategy for survival in a political environment that uses technology to identify the un(re)productive in populations. (Blas 2012, 129) Blas uses the facial recognition data of many queer men, mashed together and glitched to the point of becoming alien and unrecognizable by technology. This blatantly critiques the goals of the Tufts study, but also normative approaches to technology more broadly. Certainly, the mask itself is a twisted product of generalisation. As well as signifying a resistance to technology, it also represents the failure of efforts to distil humanity through generalising technological methodologies. But, of course, Blas' work is critical outside of its technological context; a deformed (almost like it was beaten), lurid mask the colour of a bruise has an immediate and prescient signification in the context of queer protest and police violence. I agree with Blas that there is a necessity to engage with techno-ethical issues in a material and nuanced way that reflects both on the technical and social implications of queer art making. In the case of *A20*, the point of interrogation is how technologies of ordering and control affect bodies, especially in the context of reactive work.

In A20, the software draws traditional notation, with weighted shading of the note-heads indicating dynamics, using midi data sent from Max/MSP in real-time. The max patch controls how the material is traversed through pre-built sub-patches and a modular, simple to re-construct interface. It sends OSC messages to Resolume Arena to change footage, analyses the audio and visual content of the current footage using Max's built-in FFT tools and Syphon for Jitter, converts this into pitch, velocity and audio processing information using the rules specified in the sub-patch in use, and finally outputs audio and OSC messages to the score-drawing software. This signal flow was designed to be as simple to intervene at every point by end-users, allowing performers with intermediate technical knowledge to shape how the piece is structured and interprets data.

The advantage of using my *Inrush* patches in this context was in the ability to quickly design performances that suited spaces. As my approach to the material involves heavy amounts of looping and, therefore, gradually a large amount of feedback, being able to quickly adapt the piece to fit different durations, spaces and instruments has been very helpful. Likewise, being able to make multiple algorithmic interpretations of the same material for different ensembles (for example, *Ensemble Offspring* in 2015) and have them still feel like the same piece has been a telling process in terms of understanding how material is prioritised in this piece and my practice (essentially: if there's feedback and footage, it feels like *A20*, and that leaves a broad scope for interpretation). As feedback is, in itself, a phenomenon that requires the relinquishing of control, so this patch and the freedom of the performer to cut up footage so intrinsically linked to my body a relinquishing of compositional control and an exercise in queer vulnerability.

As a starting point, we should investigate how and why performers interact with this material. Lingel and Naaman (2012) focussed on the exchange and sharing of self-filmed footage of live performances by bands, and how the sharing and distributing of lived experiences of musical performances reflected economies of gift giving and interpersonal play (p. 3). The shift from audiences 'waving their lighters… [to] mobile phones raised to capture video for rapid uploading to a variety of social media sites' has broader significance to other aspects of networked existence. (Lingel and Naaman 2012, 1) This articulation of interaction, a desire to shape and frame an individualised experience of material, has parallels with how composer-performer power relationships are renegotiated in this piece through the methodology with which the materials of the piece are structured. The system comes preloaded with hours of footage, prebuilt-means of processing it, and certainly plenty of room for implementing solutions to navigating it beyond those provided, yet – with no further structure – is outside of the general expectation of either a complete score, or an instruction on how to create a complete score. In this case, therefore, the performers are also themselves system designers, devising means of sonification of the materials, and flipping the power dynamics usually inherent in performing interactive work. This renegotiation of power dynamics extends further: the use of technology the performers participate in follows along similar lines of engagement in that, like the performers on Lingel and Naaman's stage, *my body* is what is primarily on the line. In her essay *Field Recording as a Performative Act*, Anderson notes that in field recording she 'perform[s her] body, and in these conversations caught in-the-moment, [her] voice'. (Anderson 2015) Indeed, in A20 I am present in the footage, both as the person operating the camera 90% of the time, but also because I am performing the action of filming. This is also true of the audio: my voice, me or my brother's choices in music, my brother's voice and engine noise are the core musical material. It is a unique vulnerability to be edited, manipulated and erased – but one that is key to the conceptual success of the piece.

This is the key point of renegotiation and critical interrogation of the relationship between performer/user and composer/designer: that my body is the primary subject of the control exerted in this piece. The result is an experience of my body, in this piece, that Massumi calls a '*body without an image'*: an accumulation of movements, intensities and meanings separated from the terms of their original existence. There is something about the material, the shifting, panning, zooming, bouncing camera is felt as something tactile and gestural, completely removed from the original form of its existence (my body) and felt as sensation. The exhaustion (and its anticipation) of a potentially endurance performance enforces this. To have this constant state of motion captured, freeze-framed and cut-up by technology is to create a tension between my body outside of linear time and the body of the pianist, a sort of phantom possibility that bleeds across from the screen to the performer and the audience – that this fragmentation and erasure is an inevitability. (Massumi 2002, 57-63) This has two consequences. The first brings us back to Blas: we can resist (mis)representation and control of the queer body using counter-technological techniques, while still mobilising technology as a site of resistance against normative methodologies of control and a means of users having a sensation of queer ways of knowing. The second is ethical, and reveals the consequences of the power dynamics of reactive design. Given that the usual state of affairs in physical human computer interaction places the body of the user of the system at the mercy of the designer, this approach to reactive design – with two levels of design, and the body of the designer at the mercy of the user – has offered insight into the erasure, manipulation and decontexualisation of the body in reactivity. To address this directly is to address something felt keenly in a queer context. Erasure is a reality of queer living (Eisner 2013, 37), but also offers potential for resistance. To be drowned out by constant feedback and over-exposure, too, resonates with queer experience in a palpable and material way. Mimicry of institutional technologies of control is a sign of double articulation, a reflection of the limits imposed by strategies of control but also an appropriation of how this is visualised as a criticism of that power, making it hyperbolic and pushing it to a point where its inherent structural biases are exposed. (Muñoz 1999, 77–78) This mimicry has potential for both the communication of real emotion and real change in my body un-manipulable and un-maskable by technology, but also of emotion and change brought on precisely through the articulation of power-knowledge by reactive systems. (Massumi 2002, 64) On the protocological level, this is further affirmed by Menkman. The techno-cultural 'flow' that produces this sort of reactive design relies on the build-up of norms over long periods of time. The deviations from the standard flow in this piece capture 'the machine revealing itself', but also an 'infinity of possible alternative discourses, of other possible modes of explanation and interpretation', an unforeseen incomprehension in the face of the expected. (Kluitenberg 2002 in Menkman 2011, 29–30) This is an ethical void as much as it is an informatic void, the infinity is also one of countless articulations of power and control, and imaginings of how that plays out on the surface of a body without an image, felt physically by the audience and performers.

Like Blas' work, however, this work is not purely one felt as a product of technology. The experience of erasure, invisibility and control by distant forces in interaction is one that is echoed in the realities of outer suburban and rural Australia, and especially queerness in those contexts. As much as this piece is about an unmasking and renegotiation of technological power structures taken for granted, it is also about that drive from Elizabeth to Adelaide, and from New South Wales to South Australia. The technology encompasses the discomfort and conflict of this emotional landscape – tensions between representation and darkening, between identification and disidentification, between fragmentary sensation and the perceived wholeness of a lived experience – but also questions the necessity and ethics of imposing an interpretative frame on any of it. If any conclusion is to be drawn from A20, as a piece and as an experience, it is that the richness of 'open' work is in its infinity of pathways – the horror vacui that reveals the vast possibilities of experience. (Menkman 2011, 30)

3.3. scène

"the dominant, continuing search for a noiseless channel has been, and will always be no more than a regrettable, ill-fated dogma" (Menkman 2011, 1) *Scène* exists in a space between the disintegration of classical sensibilities, and their furthest abstraction; a broken digitisation of our music culture. *Scène* revels in this decay, moments of clarity breaking down and drifting apart; in and out of sync. A process of negotiation and listening; performance as utopia at the edge of the void. When I first scored *scène* on paper, I was interested specifically in how traditional notation could be broken with glitch techniques, and how the notation of electronics could intrude on spaces reserved for acoustic instruments. In the version presented at this conference, I was interested in how I could explore new ways of renegotiating composition through a digital platform in rehearsal, allowing quick feedback and experimentation in rehearsal and performances that *fit* performers.

In *scène*, the flutist improvises from a paper score, and the electronic musician both performs audio-processing of the flutist and the generation of the score, distributing blocks of improvisatory material to player in the ensemble ad-libitum in rehearsal, with the possibility to move towards more strictly timed interpretations by performance so they can focus on audio-processing. The max-patch comes pre-loaded with the modular score materials, and some tools for manipulating them, and the scoring classes used can draw simple graphics and blocks of traditional notation. Much of this came out of the experience of working as a copyist on Cat Hope's 2017 Opera *Speechless* and, therefore, with a combination of Decibel Score Player and Adobe Illustrator The end product was a fairly polished, negotiated and collaborative effort with all the hallmarks of the composer's best work, but it was also a gruelling and time-expensive process. *Scène's* simple musical materials, which rely on their combination and dispersal for complexity, were perfect testing grounds for renegotiating a workflow that met both the desire to explore and combine the creative input of musicians and the composer in a way that was timely, intuitive, and fully embraced a queer futurity I aim to instil in my software and my works that explore improvisation.

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As of the time of writing, the key outcome of adapting *scène* with *Inrush* has been the ability to critically re-address expectations of clarity in electronics. Indeed, the use of loopers, white noise, and sine waves in the electronics part was a deliberate choice in terms of aural recognition, and pushing them and the sound of the flute to points of critical hypertrophy key to pushing against the limitations of the idea of the technological "neutrality" of the electronics and the instrument. In the context of reactive technology, as I've previously outlined, the emotional and political stakes are different and the criticism more important. Using a method of scoring that has the potential to be as "clear" as processing power allows one to explore notions of clarity and ambiguity outside of our power to process. In the context of semi-improvised music, and especially semi-improvised music engaged with queerness, this feels absolutely primary.

4. CONCLUSION AND FUTURE DIRECTIONS

Inrush aimed, first and foremost, to develop theoretical and technological approaches for making queer interactive work The research and programming associated with this project has laid an important foundational methodology for queer interactive work in my practice through a critical exploration of reactive paradigms. The technological and theoretical insights this research provides on a small-scale hint at rich territory for future research into how queerness can be used to shape critical technologies. The implications of this research will be far reaching in my future research and artistic practice, and I look forward to consolidating my code and patches into something that broadens the potential for collaboration and co-creation across art-forms and disciplines.

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Visualising the Sonic Environment

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ABSTRACT

This paper describes score creating software implemented in the visual programming language MaxMSP, the *Lyrebird: Environment Player*. *Lyrebird* analyses and visualises significant features of a sonic environment as a graphic score, that is scrolled from right to left across the computer screen. The aim of the software is to create scores from field recordings with enough semantic detail to allow performer(s) to interact with the sounds of the environment. The form of interaction is open to the performer, but is envisaged to include precise emulation of the auditory features of the recording, improvisation informed by them or a combination of both. The software was specifically designed to partially remove the composer from the loop by not requiring any further specification or intervention in any performance than the generation of the score itself. It was also designed as a near-realtime tool, in which the environment of place and time of the performance could be reflected contemporaneously.

It is part of a project to construct processes allowing for data interchange between visual and sonic media: to create a continuum in which sound could be visualized and then resonified by both live performers and digital means (Vickery 2014b, 2015).

1. CONTEXT

Emulation of the sounds of the natural environment may be one of the earliest manifestations of music. Weiss argues that the representational/abstract nature of sound is one of "central ontological" debates in sound arts (Weiss 2008:11). Examples of the evocation of nature can be found throughout the history of Western Classical Music from 16th Century vocal music (O'Callaghan 2015) to the works of Messiaen (Harley 2008). The representation of natural environments in art music was uniquely altered, however, by the introduction of recording technology and digital analysis allowing sounds to be examined in increasing detail.

Slavoj Žižek claims, "technology and ideology are inextricably intertwined" (2000: 39) and in the emergence of works for acoustic instruments with field recordings this is certainly the case. The earliest non-anthropogenic sound was recorded as early as 1889 (Ranft 1997), but it was not until Pierre Schaffer's establishment of *Musique Concrète* in 1950 (Palombini 1993, Stock 2014) that "field recordings" became the materials of Art Music. Musique Concrète lifted the constraints of the metrical/chromatic grid imposed by traditional music notation, but the manipulation of recordings remained shaped by the intentions of the composer.

The erasure of the "grid" contributed to a re-evaluation of acoustic instrumental performance, in the "Musique Concrète Instrumentale" of Lachenmann that sought to illuminate "instrumental sounds as mechanical processes" (Lachenmann 1996: 212). Together with the other developments such as Cage's *Indeterminacy* (Cage 1961) and the emergence of *Free Improvisation* (Bailey 1993) a new space was opened for the emulation of natural sounds with "extended techniques" that exponentially expanded the timbral pallet of acoustic instruments. Alvin Lucier's (1931) *(Hartford) Memory Space* (1970) is a seminal work in this respect.

> *Go to outside environments (urban, rural, hostile, benign) and record by any means (memory, written notations, tape recordings) the sound situations of those environments. Returning to an inside performance space at any later time, re-create, solely by means of your voices and instruments and with the aid of your memory devices (without additions, deletions, improvisation, interpretation) those outside sound situations.*
>
> *(Lucier and Simon 1980).*

By the 1970s, R. Murray Schafer (1933), Hildegard Westerkamp (1946) and Barry Truax (1947) created the Vancouver World Soundscape Project (1972) at Simon Fraser University, identifying field recordings as art-works in themselves. This was perhaps as a response to the resurgence of the Environmental Movement following the publication of modern foundational texts such as Rachael Carson's *Silent Spring* (1962) (dealing with the effects of man-made pollutants on wildlife) and Paul Ehrlich's *The Population Bomb* (1968) – (concerned with the impact of the exponential growth of the human population). The term "Soundscape" was invented in 1967 by Schafer (Schafer 2006) and his colleague Westerkamp noted that compositions based on soundscape recording should be "rooted in themes of the sound environment" (Westerkamp, 2002: 53). This is an important distinction, elevating the structure and morphology of natural sounds beyond the manipulations of human-derived aesthetics and formed the basis for what was later termed Eco-structuralism which states that in such works "structures must be derived from natural sound sources" and "structural data must remain in series"(Opie and Brown 2006).

Lucier's work *Carbon Copies* (1989) in which performers imitate the sounds of any indoor or outdoor environment (albeit pre-recorded), "as exactly as possible, without embellishment" in a range of configurations: recording alone, instruments emulating the recording, instruments emulating the recording with the audio muted for the audience, instruments emulating the recording from "memory or by freely imagining the sounds continuing" (ibid) was a direct influence on *Lyrebird*.

Although Westerkamp's *Fantasie for Horns II* for french horn and tape (1979) predates *Carbon Copies*, it is a vehicle for an instrumentalist performing "common practice" musical gestures: chromatic temperament, harmony and metrical rhythm. Crucially there is no attempt to emulate the unmetered and freely tempered structures in the accompanying recording.

The shift from analog to digital recording also provided crucial new tools for analyzing field recordings with a grid finer than that of human perception. The spectrogram allowed for the visual representation of sonic events that were extremely difficult to capture with traditional notation, and for a much more precise emulation of continuous timbral features through "instrumental synthesis" (Grisey 2000).

The *Lyrebird Environment Player* sits at the nexus of these technologies/ ideologies:

- continuous unedited field recordings;
- visual representation of the field recordings is created through spectral analysis;
- the performer is expected to emulate the field recording as closely as possible using appropriate extended techniques;
- improvisation may be used to create sounds that fall within the context of the field recording.

2. TECHNIQUE

The conceptual basis for *Lyrebird: Environment Player* is straightforward: the performer is provided with a scrolling visualisation of an environmental recording 12 seconds in advance of it sounding, so that the recording is sounded synchronously with its visualised auditory features as they reach the left side of the screen. This arrangement creates continuous spatial representation of imminent events in

The work augmented techniques developed for the work *EVP* (2011) in which five performers were instructed to emulate the sounds in a pre-recorded audio collage using extended techniques with the aid of a scrolling score that showed relative pitch, duration and dynamics of the EVP samples in real-time (See Fig. 1).

A delay of 12 seconds, resulting in a scroll-rate of approximately 1.3cm/s, was chosen as a trade off between the degree of detail in the visualisation and legibility for the performer. A slower scroll-rate effectively "zooms out" the visualisation resulting in a lower resolution of sonic detail, whilst scrolling information on screen becomes increasingly hard to read as reaches the "fixation threshold of the human eye" (Picking 1997). Sightreading studies by Gilman and Underwood (2003) imply a maximal threshold rate for scrolling of about 3cm/s.

Crucially, this rate allows the performer to apprehend morphological detail of "human-scale" auditory phenomena – that is, within the limits of the mental chronometry of the human auditory system and response time.

The representation of a recording in *Lyrebird* is a compromise between a traditional musical score and a spectrogram. A spectrogram represents the energy of each frequency of a sound spatially, however it is poor at "demonstrating coindexation and segmentation due to the difficulty in illustrating differences in timbre" (Adkins 2008). This problem means that the spectrogram does not necessarily "look like" what we hear because "the sensory components that arise from distinct environmental events [are] segregated into separate perceptual representations" (Bregman 1990:44) by the human auditory system.

The musical score, on the other hand, represents actions to be undertaken in order to create a sound and yet this tablature provides enough information for musicians to "read" the score and mentally form a meaningful representation of its sound. The issues of dynamics, timbre and segmentation are, to a degree, accounted for in the score as a "bound-in" consequence of the actions represented in the score.

Lyrebird attempts to mimic the timbral separation of environmental auditory events by generating and

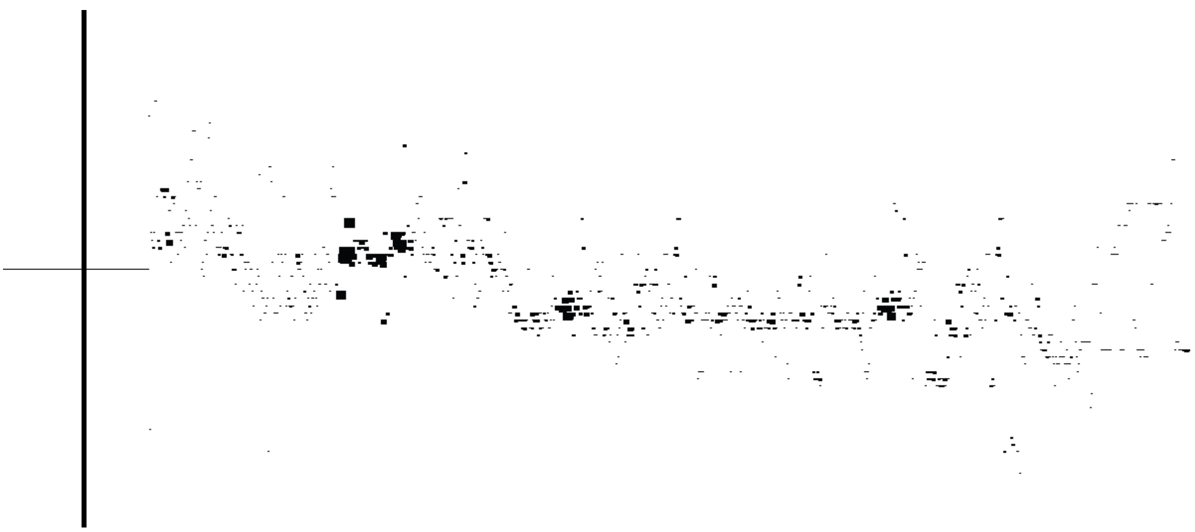

Figure 1. The scrolling scoreplayer for Lindsay Vickery's EVP [2012] showing visualized pitch and amplitude data.

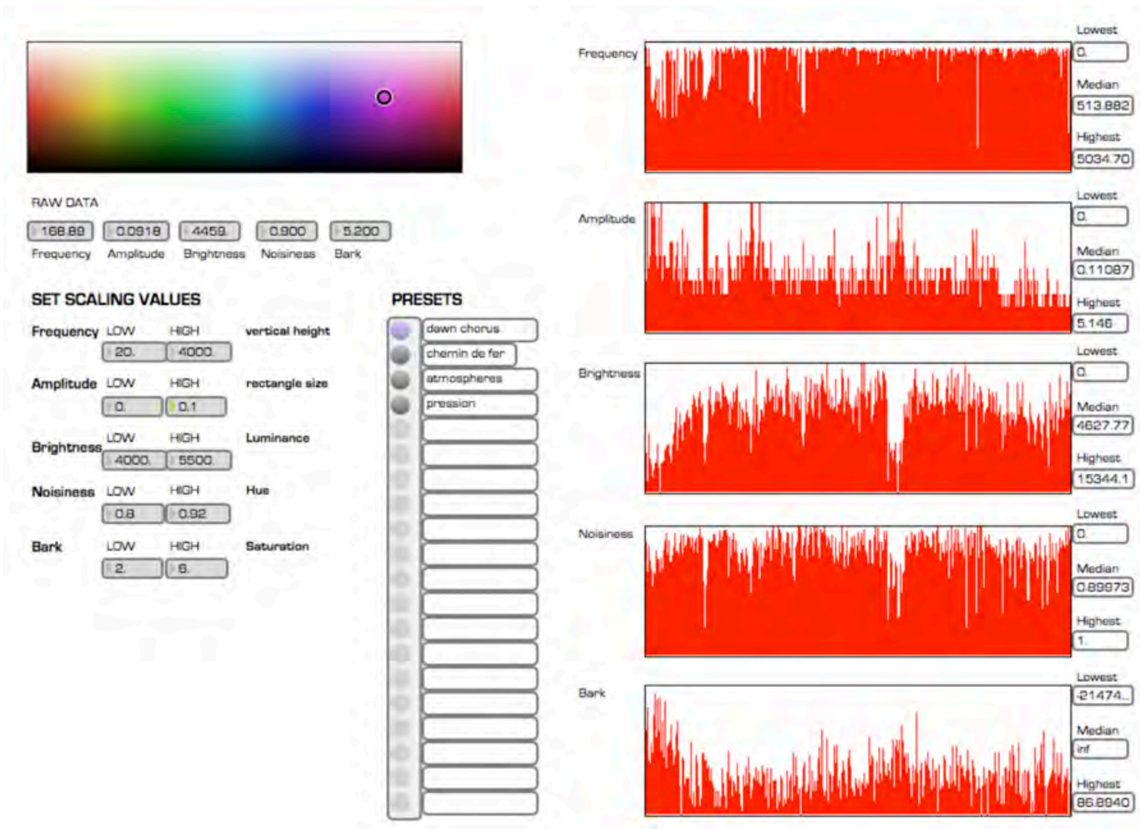

Figure 2. The Lyrebird: environment player analysis panel showing represented both raw value and scrolling multislider representation of data and scaling and preset options.

alternate form of spectrogram in which the strongest sinusoidal peak is represented spatially and coloured according to a simultaneous analysis of timbral features (brightness, noisiness and bark scale) of the whole recording at that moment. This process aims to assist the visual identification of auditory features.

The single strongest detected sinusoidal peaks detected by Tristan Jehan's `analyzer~` object are rendered as rectangles drawn on a scrolling LCD object in MaxMSP. Each rectangle represents frequency as the vertical position, amplitude as size, and brightness, noisiness and bark scale data are mapped to hue, saturation and luminance values of the rectangle.

In the current version of this work, the median of 16 bark scale values (representing the deviations from expected auditory critical bands) is used. This presupposes that the median value refers to the same critical band as the strongest sinusoidal component. In future it may be possible to model this parameter more accurately.

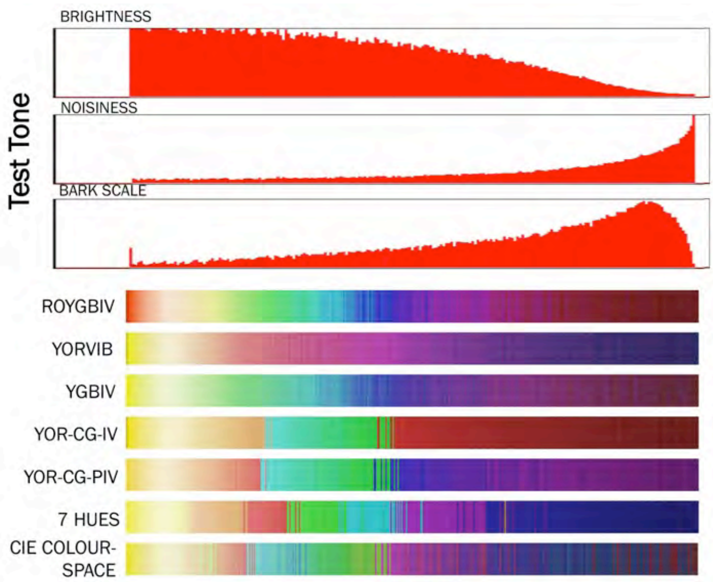

Figure 3. The spectra above depict a test tone of increasing brightness, noisiness and bark scale depicted by a variety of mappings.

Lyrebird incorporates an analysis panel (Figure 2.) that provides controls for the performer to view and scale data from the field recording. This allows for the performer to derive the most appropriate data for each individual recording and to "zoom" the visualization in or out on particular regions of activity in the recording.

To facilitate these decisions the data is represented both as a raw value and on a scrolling multislider displaying the its final scaled value, so that the performer may confirm that the scaling is capturing the full data range. The resulting colour is also displayed on a colour swatch. In the analysis panel, the performer may store the scaling values of up to 20 recordings.

Lyrebird allows for a range of mappings of timbral brightness to hue. The spectra in Fig. 3 depict a test tone of increasing brightness,

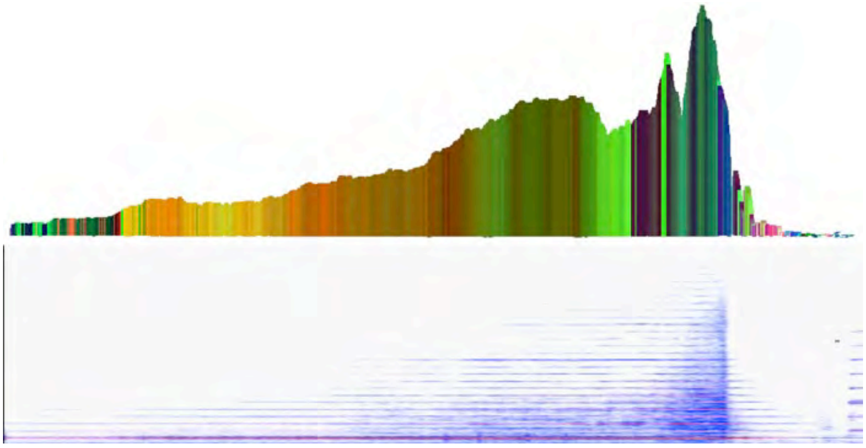

Figure 4. One of the crescendo F#s from the clarinet part of Messiaen's *Abîme des Oiseaux* represented as a spectrogram and the Lyrebird Environment Player.

noisiness and bark scale depicted by a variety of mappings.

Figure 4. illustrates a simple example in which one of the long-crescendo F#s from the clarinet part of Messiaen's *Abîme des Oiseaux* is shown represented as a spectrogram (using Chris Cannam's *Sonic Visualiser* software) (Cannam, Landone & Sandler 2010)) and the *Lyrebird Environment Player.* This example illustrates the representation of continuous timbral and amplitude changes over the duration of the note.

The example demonstrates the advantages of binding amplitude and timbre into a single form of representation in order to convey information about the sonic event, rather than representing every component frequency of the sound. This form of representation also addresses the problem that continuously evolving parameters such as timbre and amplitude, and the depiction of complex indeterminate environments such as those found in nature, are poorly captured by traditional Western music notation.

3. REPRESENTATION

The musical score is a time critical form of visualisation in which there is a strong imperative to employ symbols that signify sonic events with maximal efficiency and semantic soundness. *Lyrebird* draws on the concept that “pitch metaphors, while culturally diverse, may be based upon basic underlying mappings, stemming from bodily-based inter-modal interactions with the physical environment” (Eitan & Timmers 2010:407).

The simplest and perhaps least contested of these mappings is the vertical spatial depiction of frequency in which higher frequencies are also vertically higher on the page. The latent mapping of frequency to spatial height is demonstrated pan-culturally (Eitan and Timmers 2010:419) and in infants as young as 1 year old (Wagner, Winner, Cicchetti, and Gardner 1981).

Walker has proposed that such cross-modal correspondences are ordered in clusters. Walker claims “the same core correspondences should emerge whichever sensory feature is used to probe them, confirming that the en bloc alignment of the dimensions is context invariant” (Walker 2012:1806).

The concept of cross-modal correspondence also informs the mapping of louder amplitude to larger rectangle size in *Lyrebird.*

Application of cross-modal principals to colour is more problematic because of the difficulty of establishing a meaningful mapping of bright and dark colours. Whereas sound is mapped in a broadly linear fashion with the cochlea capturing frequencies continuously from high to low, the eye combines data from a range of different sensors – colour through three cone cells and luminosity through rod cells. The result is that vision is not mapped in a linear fashion. The arrangement of rods and cones gives rise to anomalies such as the non-sequential perceptual “brightness” of colours such as yellow, cyan and magenta in the colour spectrum (Fig. 5).

CIELAB colour space (Figure 6.) attempts to mimic the nonlinear response of the eye by modelling cone responses. The notional colour spectrum provides a palette from which colours representing sonic features or instruments might be chosen in a musical score. For most people this chart appears segmented into families of similar hue (yellow, orange, tan, green-blue etc) and distinct but related hues may lend themselves to the

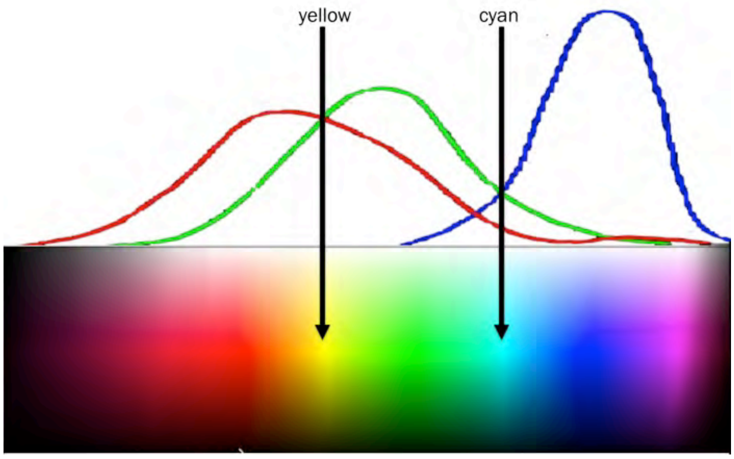

Figure 5. Light frequencies between the colour-sensitivity responses of the - red, green and blue cone cells (such as yellow, cyan and magenta) may appear brighter because they are perceived in regions where the sensitivity is attenuating.

Figure 6. A notional colour spectrum based on human visual perception from white to black (based on CIELAB colour space (Hoffman 2003) and Bruce MacEvoy's Artist's Value Wheel (MacEvoy 2005).

representation of timbral variation within a sonic feature or instrument.

Lyrebird allows a range of timbre to colour mappings: ROYGBIV, YORVIB (bypassing the green-blue channel), YGBIV (bypassing the Red-Orange channel), YOR-CG-IV and YOR-CG-PIV (comprising three light-to-dark spaces), 7 Hues (YORGCMB) and CIELAB COLOUR-SPACE. The performer may experiment to discover which mapping is most suited to a specific field recording.

As sounds in nature are often arranged in frequency/timbre bands – frogs, large birds, small birds, crickets etc – some mappings prove to be more effective at representing a particular environment. The score may also be viewed against a black of white background (Fig. 7). *Lyrebird* does not at present support fully customised mappings.

Future versions of *Lyrebird* may incorporate recent research at *The Visual Perception and Aesthetics Lab* at the University of California Berkeley, suggesting that there is a high degree of correlation between mappings of colour-to-sound in non-synaesthetes. Griscom and Palmer have proposed that there are systematic relationships between colour and a range of musical phenomena including timbre, pitch, tempo, intervals, triads and musical genres (Griscom and Palmer 2012, 2013).

Colour provides a great potential for the formation of Perceptual Discriminability in a musical score. One obvious approach, for example, might be to employ a colour scheme that maximizes the distinctness of separate musical phenomena such as instruments, voices or sound sources. Similar requirements have been studied for the creation of data visualisation (Tufte 1990), transport maps (Green-Armytage 2010), and websites (Stanicek 2009). Recent research, however, has indicated strong perceptual correspondences between colour and a range of sonic phenomena (Prado-Leon, Schloss & Palmer 2011), suggesting there may be more intrinsic semantic value to be gained from colouring the score.

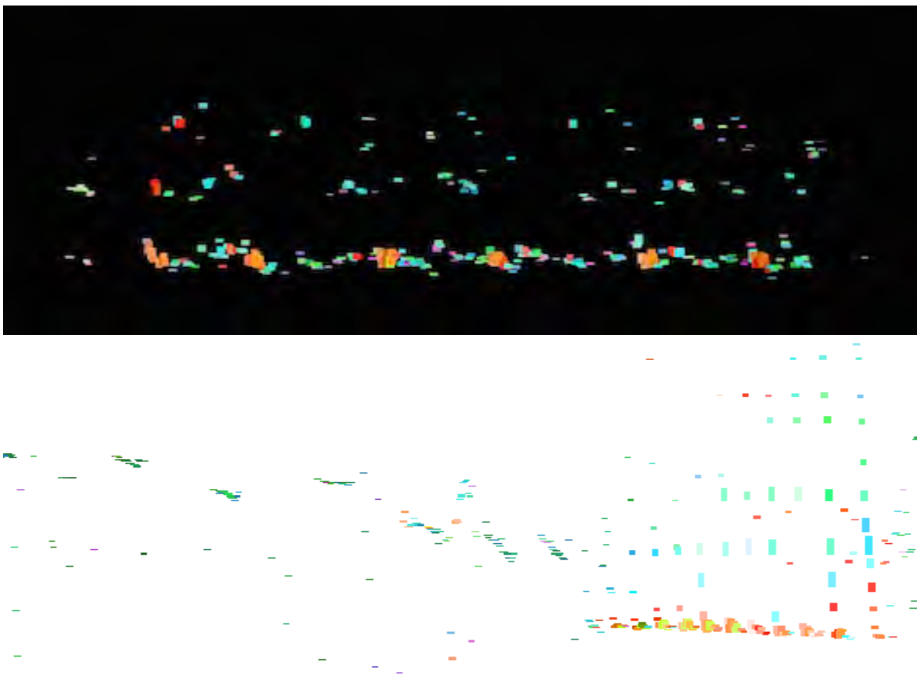

Figure 7. Screen shot of black background *Lyrebird* score from *Bullfrogs and Rainstorm* (excerpt above) and Screen Shot of white background *Lyrebird* score from *Whistlers and Crickets* (excerpt below).

4. DISCUSSION

In this project, the objective of interaction between a live performer and environmental sounds in works such as Lucier's *Carbon Copies* was broadened through the addition of a visual representation of the field recording. While not strictly "real-time" (recorded sounds are delayed by 12 seconds), this environmental sound scoreplayer allows performer(s) to engage with natural sonic environments in a site-specific manner, using field recordings and sonorous objects from the vicinity of a performance. It

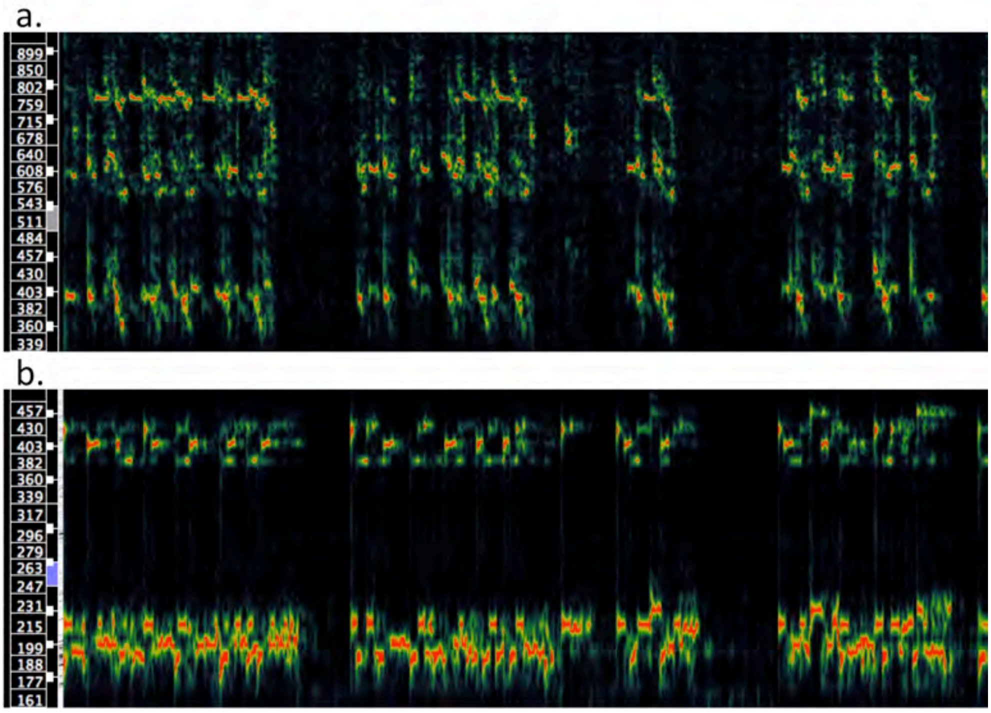

Figure 8: *Bullfrogs and Rainstorm:* comparison between (a) field recording 339-899Hz and (b) piano performance 161-457Hz.

provides a mechanism for the performance of, or improvisation around, significant sonic features from the natural environment.

The figures below explore the effectiveness of these objectives through the comparison spectrograms of the source field recordings and the performances of a number of musicians. The spectrograms depict comparable frequency ranges, although the performer spectrograms are uniformly an octave lower than those of the field recording. The titles of the recordings are those given by the original recordist Philip Kenworthy.

Figure 9 compares the field recording *Bullfrogs and Rainstorm* with a pianist's performance. The performer's relationship to *Lyrebird* is the most "score-like", in that the pitch, rhythmic and dynamic contours of the bullfrog croaks from the field recording are adhered to with a great deal of precision.

The task is perhaps simplified because the pitch range of the croaks is limited to about 3 semitones, however the spectrogram indicates that this method of synchronisation of the recording and the performance is effective in this instance.

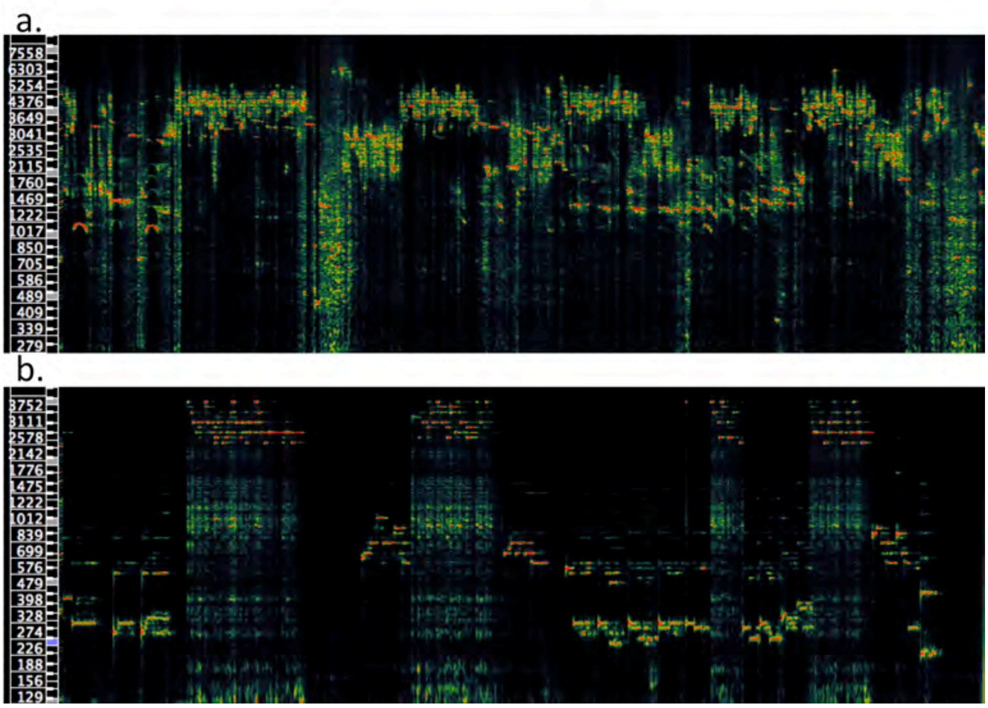

Figure 9: *Kookaburra Sunrise:* comparison between (a) field recording 279-7558Hz and (b) piano performance 129-3752Hz.

In a case where a more complex sound environment comprising a range of birdsongs is used, such as Fig. 10, the task is considerably more complex. Birdsongs are often too high pitched and rapid to be emulated entirely accurately. *Lyrebird* aims to provide information at a human scale showing the contour of extremely rapid birdcalls rather than precise detail. Here the same pianist aims to portray three bands

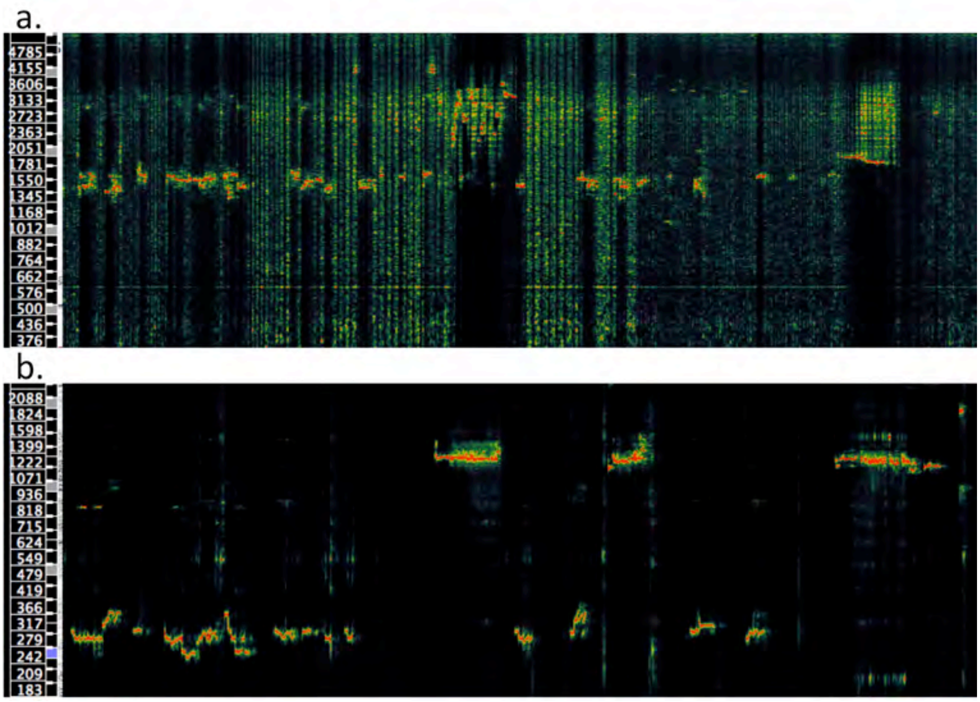

Figure 10: *Whistlers and Crickets:* comparison between (a) field recording 376-4785Hz and (b) bass clarinet performance 183-2088Hz.

of activity in different ranges and is successful until the bands have simultaneous activity (about half-way through the figure), at which point activity in the highest band is ignored.

In a complex environment such as the recording *Whistlers and Crickets* (Fig. 11) there is too much data for the performer to emulate the complete environment. Again the performer, this time on bass clarinet chooses specific features to emulate. A potential solution to the emulation of complex environments is the use of networked players displaying activity in different bands for a number of performers.

Lyrebird does not represent the sonic events on a grid to indicate frequency, and it is evident that the performer here "overshoots" the high frequency events, performing them about an octave too high in relation to the lower pitched layers.

In Fig. 12, the performer's aim was to interact with the recording through both emulation and improvisation. The field recording spectrogram shows the gradual fading of repetitive cricket sounds, followed by a prominent birdcall.

The percussionist emulates only the birdcall and then mimics the cricket sounds once they have ceased. The passage suggests that *Lyrebird* can provide and effective representation of the sonic environment that allows the performer to interact by taking over features from the recording.

Lyrebird allows for interaction with pre-recorded non-anthropogenic sound environments. The degree to which an interaction is meaningful is self-evidently dependent on the performer(s) abilities. Examples of this work can be heard at (https://lindsayvickery.bandcamp.com/album/works-for-instruments-and-field-recordings). However, unlike many musical experiences the potential for precise synchronisation of a performer with

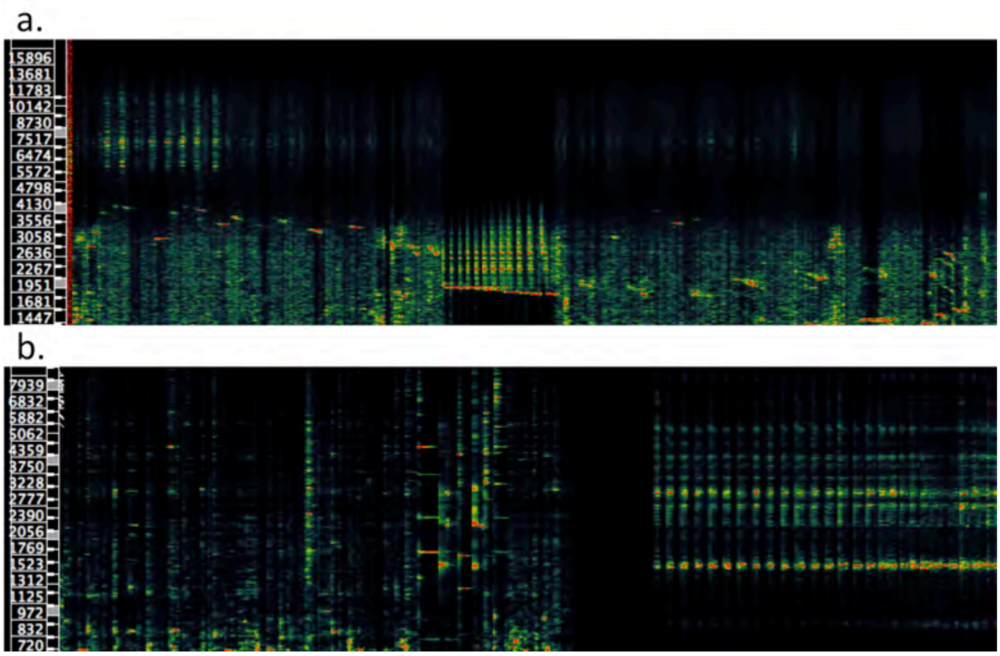

Figure 11: Whistlers and Crickets: comparison between (a) field 1447-15896Hz recording and (b) percussion performance 720-7939Hz.

seemingly indeterminate sonic events arguably has an intrinsically interesting quality. The evaluation of the accuracy of performer emulation is something of an end in itself, and this includes both the degree of acoustic reproduction of the sounds (as demonstrated in Figures 9-11) and the performer's ability to "enter into" the soundworld of the recording through improvisation.

5. CONCULSION

Efficient and semantically sound notation is crucial for the development of effective notation for screenscores. The compromise between a traditional musical score and a spectrogram adopted in *Lyrebird: Environment Player* is part of an on-going project to explore means to better capture nuances of sound such as timbre, temperament and envelope morphology using shape and colour parameters (hue, saturation and luminosity).

The arrangement of displaying data before it is heard proves to be an effective means of preparing the performer(s) with spatial and timbral information comparable, in general terms, to that of traditional music score.

Future developments of the software may be further enhanced to reflect more complex or customised colour mapping. Bark scale values, that are currently averaged may be modelled more accurately across the entire frequency spectrum, for example. Other spectral parameters such as diffuseness may be exploited as potential bearers of timbral information. Higher order Auditory Scene and morphological features of spectra may be taken into account such as flux, contour and stream segregation, pursuing the goals of composers of Spectral music (Fineberg 1999). Such developments may allow for data to be assigned to particular instruments within an ensemble dynamically through interpretations based upon range, timbre within and polyphony.

Multiple scoreplayers have already been networked together, allowing ensembles of performers to interact with visualisations that focus of varied frequency, amplitude and timbral parameters of the same recording.

Lyrebird can also operate as a tool in the creation of fixed works using a single field recording, allowing for greater annotation of the score or to generate timbral information for an otherwise fixed score as is the case in *the miracle of the rose* (2016) (Vickery 2015).

A current project is seeking to develop means for communicating data to the more portable Decibel Scoreplayer (Hope et al 2015).

The examples of performances with *Lyrebird* suggest it can effectively convey useful information to the performer and act as a vehicle for live performers to engage with field recordings.

6. ACKNOWLEDGEMENTS

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The field recordings discussed in section 5 were recorded by Philip Kenworthy.

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EXPLORING INTIMATE SPACE: IN THE PURSUIT OF EMBODIED LISTENING VIA MICRO-SPATIAL SOUND SYSTEMS

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ABSTRACT

This paper explores the development and possibilities for a series of custom-built micro-spatial sound systems suited for composition, performance, software design and installation. Each speaker system (*Speaker_Forest, (solo*), and *(duo)*) is built with hexaphonic and or dodecaphonic audio capabilities, with the potential to be expanded further. In addition, these sound systems are built on a budget and explore alternative modes of sound diffusion through multi-channel tracking in space. The second half of this paper assesses possible spatial composition techniques born from these speaker systems with a focus on embodiment as a method of audience engagement. The findings of this paper reflect the personal experiences of the first author; to this end, the paper makes use of a first-person narrative format in some sections in order to most directly convey the experiential elements of this work.

1. INTRODUCTION

Headphones and personalised listening environments in the home have revolutionised listening since the inception of this technology in the 20th century. Shared listening environments are often politicised in their public spaces by the social context of any given time. These listening environments are likewise often gendered to prioritise the masculine listening experience over others, as noted by sonic arts theorist Holly Ingleton [1]. As someone who has brushed against this hierarchy constantly in my own experience, I became very interested in creating listening spaces where these relationships are put on equal ground. In essence, I pursued the idea of a 'safe' listening space for people, which could also engage acoustic architecture through custom-designed and built sound systems. Diffusion performance was an element to be considered too; the key with this project was to create an open-ended system that would benefit not just performance, but could be used as a tool for composing, for installation and as a tool for new exploring methodologies in sound diffusion.

I am keenly interested in the concept of embodied listening. Katherine Hayles' *How We Became Post-Human* [2] states that we are all subject to cultural constructs, individual experiences, place, timing and spaces (locations, as well as mental space). We know that our relationships to technology become subverted through embodiment: for example, we treat our phones, not as physical objects, but as a transmitter of our loved ones, of work and of our lives. The voice transmitted through these radio waves inhabits a quasi-Anthropomorphic quality to the object itself.

As an artist wanting to conduct people towards phenomenological experiences, it was important to not only develop music, but create opportunities for shared listening 'performances' too. Installations seemed the best opportunity to do this; in their construction they could be primarily concerned with discreet, small-scale spatial sounds whose intimacy encourages listenership between one to three people. The rooms in which these sound systems were set up would also need to be reflective or reverberant to emphasise aspects of the sounds.

Figure 1: The custom-made *Speaker_Forest* sound system and composition tool.

Portable and cost effective spatial installations are few and far between and often the specifics of an installation will stay specific to a piece, rendering their use for one project only. Spatial music technology is a relatively new field of music and is usually privileged to the gallery or university institution. Ultimately the goal to create discreet spatialised works which are portable, cost-effective and could be used in multiple creative iterations by those without university training was the goal to open up the field of spatial works outside of the institution. Inspiring people to engage in a style of sound art they may not have had the opportunity to in the past was one of the core reasons for pursuing embodiment as a primary compositional focus.

Through my phenomenological viewpoint, I aim to explore tools or sound structures in which engage in embodiment and see how music can play a part in generating unique experiences - collective or singular - through custom-designed and built sound sculptures. With this in mind, I set off to create a series of micro-spatial multi-channel sound installations with the purpose of being able to compose detail-oriented spatial works.

Figure 2: *(solo)* presented as an installation and the first iteration of the speaker dome series

Figure 3: *(duo)*, the second iteration of the speaker dome series.

2. RELATED WORKS

The collection of sound installations which make up the exhibition 'Composing Environments 2.0' (which featured *Speaker_Forest* [figure 1], *(solo)* [figure 2] and *(duo)* [figure 3]) drew from four primary sub-disciplines, pertaining to the development of micro-multichannel sound interfaces, their role in diffusion performances, as well as sculpture and performance art.

2.1. Design and Diffusion

Spatial composition and diffusion performance in electro-acoustic music is a well-established practice, and has diversified hugely in the last 100 years to explore new musical territories. Recently, it even been adopted within the commercial film industry; in 2012 Pixar's *Brave* was the first film to premier the immersive overhead Dolby Atmos system using the 7.1.4 speaker configuration.[1] [2]

Towards the realisation of the *Speaker_Forest* [as seen in figure 1], *(solo)* [figure 2] and *(duo)* [figure 3], there were a number of works that that inspired me to explore these ideas further. Pieces such as Janet Cardiff and George Bures Miller's *40 Part Motet* [figure 4] [3] have been instrumental in the popularization of electroacoustic spatial sound work, and are viewed as occupying sound art and sculptural fields. When the music plays, the empty space becomes activated, unlocking its otherwise forgotten acoustic properties. The speakers are grouped in SATB choral formation singing Thomas Tallis' 1573 *Spem in alium*. The idea of having multiple voices individually represented each by a speaker and their how they engage with the acoustic architecture in the *40 Part Motet* was a key influence in the design of *Speaker_Forest*.

Figure 4: Janet Cardiff and George Bures Miller's *40 Part Motet,* photo courtesy of cardiffmiller.com[3]

Tristan Perich's *Microtonal Wall* [figure 5] differs as it was created with 1500 piezo speakers with dedicated microprocessors which are 'tuned individually, creating a pitch continuum'.[4] Although the scale of this installation showcases a wide tonal range as its sonic output, very finely tuned, it is not able to produce audio signal aside from the tone in which each speaker was initially designed for. The tension begins as you move along the space and listen to the minutia of the speakers as well as the macro-sound picture.

Figure 5: *Microtonal Wall*

Robin Minard's *Silent Music* [figure 6] finds some middle ground between the 40 Part Motet and the Microtonal Wall: it was constructed using minimal materials but using the gallery space, speakers wire and outputting four channel audio. [5] The quadrophonic playback benefits composers through a familiar spatial

1 http://www.hollywoodreporter.com/news/peter-jackson-considering-dolby-atmos-318708
2 http://www.dolby.com/us/en/technologies/home/dolby-atmos.html
3 http://www.cardiffmiller.com/artworks/inst/motet.html#

format. Although the installation is modular the relationship between the speakers is more focussed on the delicacy of the sound world than exploring compositional possibilities with the number of speakers. It focusses instead on the relationship between each of the speakers and how the audio itself interacts with the space, each speaker placement clustering in different configurations depending on the space.

Figure 6: Robin Minard's *Silent Music* courtesy of http://www.robinminard.com/minard.content.php?id=57&sh=0

In undertaking building my work, I wanted to explore the space between each of these works. I wanted to pursue modular installation design that also reflected a wider channel output. This could then be used for finite and delicate composition between each of the smaller speakers. For example in Minard's work there are a maximum of four channels, limiting one's options to compose in a fully spatial way – you can control groups of speakers, but not send audio to the individual speakers themselves, pinpointing it. This focus on speaker arrays became a key focus in the conceptualisation and development of *Speaker_Forest*, *(solo)* and *(duo).*

2.3. Sculpture and Performance Art

Visual and spatial considerations were important when developing the housing for *(solo)* and *(duo)*; space, reflection and resonance became key elements for the possibility of multiple compositional ideas.

Anish Kapoor's 2008 *Untitled (*figure 7) stainless steel sculpture is one of many iterations in a series by the artist exploring reflection, light and space. [6] Additionally, the curves of the stainless steel hemisphere offer unusual sound reflections, uncovering a unique sound world. The design for the two installations primarily focussed on the type of metal, the depth of the curvature and the shape itself.

Figure 7: Anish Kapoor's *Untitled*, courtesy of: http://anishkapoor.com/721/untitled-21

The layout of elements of *(duo)* and the panels of *Speaker_Forest* draws on the relationship between object and audience, or in this case, performer and reception. In order to experience the works properly, listeners must engage with the work physically, in part due to their position in space and relation to one another. The idea of performed sound sculpture was inspired by the 2010 performance series at MoMA by Marina Abramovic (shown in figure 8).[4] The configuration of shared listening and private listening were main themes in *(solo)* and *(duo).* The idea of confronting the listening space between two people was especially explored in *(duo)* in the sense that the configuration of the speakers were positioned across from one another making dual listening possible and recommended the way people interact with the space.

Figure 8: Marina Abramovic, *The Artist Is Present* https://www.moma.org/calendar/exhibitions/964?locale=en

3. DESIGN, DEVELOPMENT AND PARTICIPANT EXPERIENCE

This section will discuss the hardware, design and the significance of the design implementation towards the creation of sound work.

3.1 Hardware

Speaker_Forest, *(solo)*, and *(duo)* were all constructed as multi-channel speaker systems with the possibility of being adapted, extended and customised to create unique and dynamic micro-spatial sound experiences for listeners. This section will lay out the design, fabrication, and implementation of these systems. The fabrication of *(solo)* and *(duo)* came in several stages: first, implementing the steel hemispherical design by contracting a metal spinner to make custom-made cases with lips which could be mounted. Next, the construction and mounting of the speakers and amps. Four speakers per amplifier in series-parallel distributes the signal flow

4 https://www.moma.org/calendar/exhibitions/964

evenly to avoid overheating. [5] contains further information about this circuit.

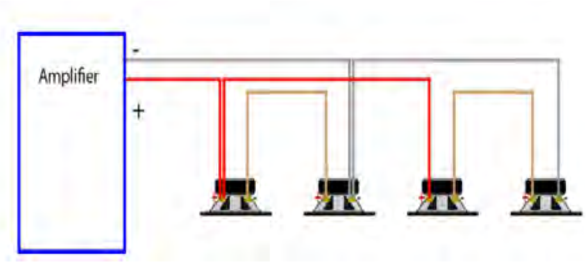

Figure 9: Signal flow from series-parallel circuit.

Each installation is comprised of between six to twelve circuits, and with four speakers per amplifier. The composer can emphasise space and spatial relationships between the speakers through compositional techniques such as panning and phasing, thus 'choreographing' where the sound may travel in the space (a nod to Wishart's notion of spatial motion). How each of the speakers are mounted in their installation also creates delicate and unique signals, some of which move in and out of phase with one another. The best example of this is with *Speaker_Forest,* discussed below.

3.2. Speaker_Forest

Speaker_Forest (shown in Figures 1 and 10) is the first of the micro multi-channel sound installations: it is also a performance tool and diffusion environment for composers and performers. Comprised of twelve audio channels, composers have the opportunity to go beyond usual quadrophonic spatial formats and try hexaphony and dodecaphony. The twelve audio channels are connected through an aggregate audio device and are addressed by Ableton Live. The expansion of multiple channels to be selected over one or more audio interfaces suggests that this installation has the potential to be continually expanded in size and scope to fit a wide range of compositional contexts. The speaker sizes range between 27mm - 40mm creating light-weight, directional structures that float from overhead, forming multi-layered, canopy-like relationships between one another. The audio channel mapping can likewise be customised to the composer's needs as well as the configuration of the panels to one another, which means the possibilities for multiple rigs are up to the mindset of the creator and the pattern of the audio channels as important to consider as sections of an orchestra.

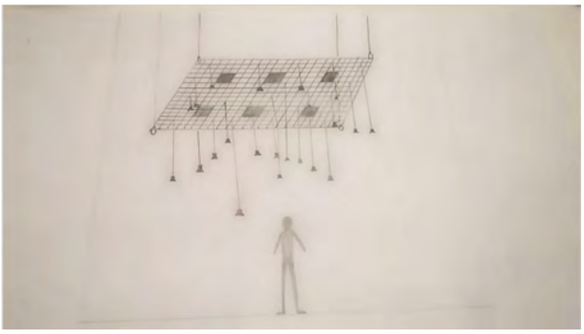

Figure 10: early conceptual sketch of *Speaker_Forest.*

Speaker_Forest hangs above audience members, with the speakers loosely falling down at varying levels, giving listeners the opportunity to physically interact with the space by walking under and through the speakers, like moving through the 'canopies'. The acoustic reflections and arbitrary nature of the way in which the speakers each hang down engage the surrounding space inwardly to be experienced as you walk through them, and outwardly depending on which direction the speakers are facing and what they are aiming. As one walks through the 'canopies', the phasing between each of the speakers creates delicate, timbral textures specific to the height of each listener.

Further documentation of *Speaker_Forest* may be viewed at: **https://www.youtube.com/watch?v=DXZodfD7Ttc**.

3.3. *(solo)* & *(duo)*

(solo) (shown in Figure 2, above) is the second iteration in the series of micro-multichannel spatial sound works; a six channel semi-enclosed metal hemisphere is home to twenty-four miniature speakers. This work was constructed with the intention of being primarily used as an installation. The 12mm speakers line the outside of the spheres facing inward, mounted behind the bowl pushing a clear audio signal through 10mm holes. In this work is that the participant can choose to engage by simply leaning into the enclosure. The installation is also battery powered, allowing for maximum portability for outdoor settings. The focus for this piece is on the audio signal and the reflections in the small space itself. The direction of the speakers all facing inwards, and lining the inside of a metal hemisphere gives distorted and immersive reflections, and timbral variation depending on what musical materials are being used.

One can see documentation of *(solo)* at the following link: **https://www.youtube.com/watch?v=q34ewCQ_-D0**

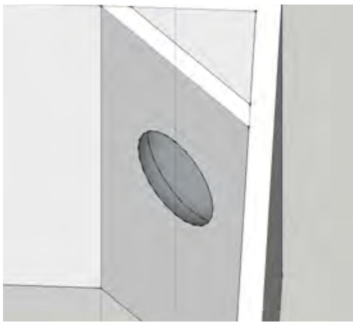

Figure 11: Designing the installation view of *(solo)*

This work is also a modular one: multiple stainless steel cases which house more speaker arrays can be easily added or subtracted, and their location in relation to one another can be altered, befitting of performance or large-scale installation. While *(solo)*'s primary purpose was intended for the creation of intimate listening spaces for one person, the expansion of the installation to two hemispheres with 12 ch audio and 48 speakers created a new and dynamic space for multiple listeners to engage with, as found in *(duo)* shown in Figure 3, above.

In *(duo)* the 48 speakers are housed behind the sphere, projecting through 4mm holes, making the audio signal resonate the metal casing. The sound qualities within the space as a result are less directional and reflective like *(solo)* but more resonant. The hemispherical cabinets can also be mounted in various configurations. In this iteration the sculptures were faced opposite one another.

Further documentation of *(duo)* may be viewed at: **https://www.youtube.com/watch?v=oKChuA_VAZI**

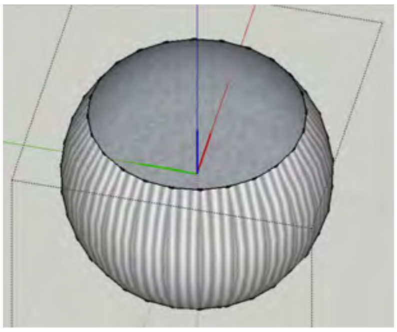

Figure 12: stainless steel casing design for *(solo)* and *(duo)*.

3.4. Software Design

In addition to a new hardware device, *(solo)* and *(duo)* make use of a customer software interface. The GUI will allow composers and performers greater expressive control while writing music and performing. The primary control of the GUI is to govern the volume of each section, and can easily be customised in terms of gain controls depending on the needs of the piece. It was written firstly with the idea for live performance, in order for the performer to have greater control over the numbers of signals coming from Ableton Live all at once.

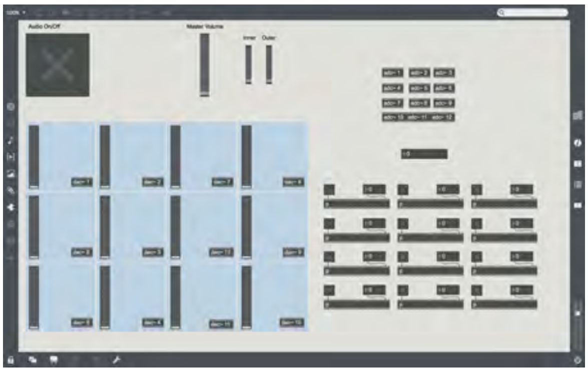

Figure 13: The *Speaker_Forest* diffusion interface: each channel is able to be controlled by a midi device and can be configured through a DAW for performance.

Figure 13 depicts the main GUI screen. It has an 'on/off' toggle to enable/disable audio output. Once toggled, it tells each **adc~** object to begin accepting audio from Soundflower and each **dac~** object to start outputting audio to the aggregate device. Soundflower is an external program which functions as a digital audio interface within the computer, allowing the user to route audio between programs (in this case Max and Ableton).

There are three main volume controls of Figure 13, seen at the top in the middle. There is a master gain, a gain for the inner channels (3, 12) and outer channels (1, 2, 7, 8, 9, 10, 11, 4, 5, 6). Each square in the blue grid corresponds to a speaker 'section' in the installation. The slider on each square allows for individual gain control of each of these speaker sections.

On the bottom right, there are twelve individual subpatchers which route each input signal to the 12 dac~ outputs, and allows output randomisation (detailed below). The toggle attached to each subpatcher enables/disables output randomisation, and the number sets the randomisation rate.

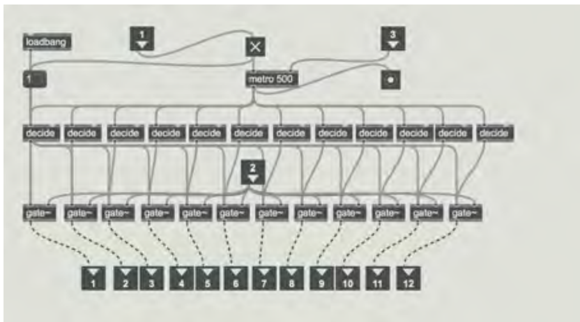

Figure 14: Max sub-patcher detailing

Figure 14 details the sub-patcher. It has 3 inputs (toggle randomisation, audio input, and randomisation rate) and 12 outputs (all audio), labelled 1 – 12 on the bottom. Each audio output receives its signal from **inlet 2** via a **gate~** object. Each **gate~** object can receive a message of either 0 (output disabled) or 1 (output enabled). When the Max patch is opened, the **loadbang** object ensures each outlet has output enabled at startup.

Inlet number 1 takes input from a toggle in the main patch, and controls the **metro** object, which outputs a bang regularly at the specified rate (default 500ms). Inlet number 3 controls this rate. Every time the **metro** object bangs it triggers a **decide** object for each gate, which chooses randomly between 1 or 0, sending the result to the attached **gate~**. In this way, which gates (and therefore which outputs) are open or closed is randomised every time the metro bangs.

There is a randomise speaker function which will send an input signal from Ableton randomly between all 12 speakers to a certain rate, if toggled. This was to encourage new composers of spatial music the opportunity to interact with generative composition and to supply quickly gratifying spatial composition techniques to beginners.

The GUI allows composers and performers greater expressive control while writing and performing music. Like a conductor, the primary role of the GUI is to govern the volume of each section, and can easily be customised in terms of gain controls depending on the needs of the piece. It was written firstly with the idea for live performance in order for the performer to have greater control over the numbers of signals coming from Ableton all at once. This allows the composer greater flexibility and control writing spatial music as the GUI offers the opportunity for on the fly diffusion style music as well as fixed media. The opportunity to have multiple options to send the audio within the space proved crucial in the conceptualisation and composition of the audio.

4 . AUDIO & CONCEPT

Musical development was in part conceptual and in part informed by the installations themselves. It became apparent while writing music that the line between pre-composed musical ideas conceived prior to working with the rig versus ideas informed by composing with the installation were extremely blurred.

Speaker_Forest informed the musical structure through 'diffusion choreography'; inhales and exhales move inwardly and outwardly between the panels, repeated breathing forming a motif which became the base of the musical structure.

Building on Idhe's notion of the voice possessing an ‘auditory aura’ which ‘physically invades’ the body of the listener, the music itself was based on my first-person phenomenological experience in order to capture a 'memory space' [8]. In favour of using space as an alternative, Wishart's theory of the lattice [9] was put to the side; instead of just using diffusion 'spread' of the audio signal, this piece also engages location and panning techniques.

Conceptually, the music grew from the idea of sleeping next to my partner who suffers from serious breathing problems as there was a period of time where he was choking in his sleep without waking. This piece was written initially to explore the relationship we have to the body and technology but became a reflection of my relationship with my partner who suffers from asthma and chronic ill health. The piece forms my point of view as we are going to sleep, hearing regular breathing transform into irregular breath as I toss and turn. The music became an experiential mood-diary of what it felt like nursing someone you care about back to health. There are elements of trying to convince yourself that everything will be okay, combined with the panic of not knowing whether you're imagining sounds that are in your head or whether they're actually coming from your partner. This was explored through audio effects such as echo, panning and long reverb to symbolise the 'imagined' breath.

I realised that the piece as I was writing it became less about how we embody technology as humans, and more about how people are survived by technology and our reliance on it to keep us well. In my case, this was my dependence on my phone to call the ambulance in an emergency. The piece is about our relationship with technology as people, and the anxiety of never quite feeling comfortable with putting someone's health in the palms of a program.

In addition to this work, I approached friend and artist Mo Zareei to write a test piece for *Speaker_Forest.* As an experienced audio artist with Ableton Live and spatial composition, he quickly understood how to compose for the unusually large number of channels, exploring harsher, noise tones which bear resemblance to his brutalist sound sculptures[5]. It was quick and effective, the high pitches bouncing off the reverberant flat surfaces and creating a kind of 'twinkly blanket'. What I took away from Mo's contribution was how versatile the sound system is, and how it can be engaging for many different styles of music, be it ambient or otherwise. It was especially beneficial for me to see how our different compositional aesthetics both worked in such an immersive sound environment.

The audio component of *(solo)* was an iteration of the same concept explored in the *Speaker_Forest's* music, comprised only of breathing sounds. In this work, the inhaling begins at the centre-most point of the dome and exhales with rushed panning out to the edges of the dome. Whilst the audio track is a seven-minute loop, over time the breathing becomes quieter and quieter due to the installation being battery operated and running out of power. This part of the installation informed the piece with sense of mortality and finality. Breath emanating from a non-living object humanises it and embodies the traits we associate with living, making this sound experience very personal as it asks us to confront our mortality in a very intimate way.

In *(duo),* the sound is more obliquely related to themes of breath and the body via the desire to address the effect of urban and rural air pollution from anthropogenic sources upon natural, non-man-made environments. In turn, this pollution impacts our own bodies. I aimed to show that although despite the popular association of air pollution with urban and rural areas, air pollution produced by anthropogenic sources is impacting non-urban and non-agricultural areas too. Some of these areas are considered 'remote' from anthropogenic pollutant sources, showing that our impacts on humans are incredibly far-reaching. It also suggested that at many levels in where you live in the world, there are subtle changes in our own experiences of air pollution from taste, sight, smell, to hearing (not so much touch taste).

I decided to show the New Zealand bush which is often associated with our '100% pure NZ' brand, as slightly 'discoloured' with harsher sounds. Are they the sounds of cicadas or are you detecting in the background or is it something else, more unpleasant? The noise blends in with the natural environment making it harder to discern what is natural and what is not. Inspired by the ambient music of Alva Noto, I used tone generators to produce 15700 Hz - which is the same frequency value

5 http://m-h-z.net/soundsculptures/

as CRT TVs - as harsh sine waves and triangle waves. These tones circle the space, creating a tension over a five-minute period and are piercing in character, but subtle. Some people are unable to hear this high pitch at all, they will live happily listening to the bird song and think nothing of it. Some people with more acute hearing will recognise that this environment has been 'tampered with' by humans. This is very deliberate, so as to emphasise the permeation of human culture and industrial evolution upon the wider world. Based on my research of air pollution from the WHO, NASA, and New Zealand's Ministry of the Environment, I was able to make informed musical choices. Using musical elements against the backdrop of Wellington's Otari-Wilton bush walk engages with Brian Eno's concept of using ambient music as a 'tint' to emphasise aspects of the surrounding environment.

High frequencies such as 15700 Hz seems to have a range of responses from people due to the association with CRT TVs, and largely that tone is often felt in an unpleasant way. After watching this video[6] it was clear to me that as humans are made up largely of water, our bodies would respond in similar ways to sound waves, hence my compositional preference for high pitched sines over traditional noise music methodologies. The more complex the partial makeup, the more complex and possibly frenetic our responses could be.

The three installations were shown at 17 Tory St in Wellington, New Zealand during October 2016. Each work within same concrete room rectangular occupied an important role: hanging above audience members, hidden in the corner and two hemispheres facing one another, mounted within two plinths.

5. INSTALLATION AND PARTICIPANT EXPERIENCE

As the listener approaches the space they are greeted by intricate and complex – if not slightly intense - sounds from a somewhat indistinct source. As the configuration of *(duo)* and *Speaker_Forest* for installation is modular, this setup may be altered depending on the music written for it and how the composer would like the audience to interact with the sound for any given space. *(duo)* particularly draws on the relationship built between performer and reception, or in this case object and audience, inviting multiple listeners between the two pillars to engage.

Being that *(solo)* was battery powered, this directly impacted the nature of the audio. The audio work mimics breathing, of being up close right next to someone's mouth. Over the course of the piece, the breath would get quieter and quieter, and slowly 'dies'. It gives the work a feeling of mortality and finality which seldom comes with everlasting loop-based audio installation work.

(duo) took a different approach compositionally. A binaural field recording of the Wilton-Otari bush walk in Wellington was split between two hemispheres. The hemispheres faced one another, mounted in two plinths which helped to encourage people to sit and be immersed in the space between. In the audio, high-pitched tones mix with white noise to imply that the natural world is not totally untouched by human influence. It refers directly to the strong Wellington wind and how air pollution travels quickly over the city right into the bush. Although levels of air pollution are relatively low in New Zealand, the sonic allegory of the pollution, 15kHz frequency, generates many different reactions from listeners: indifference, pleasure or genuine pain/ discomfort.

The immersive nature of all three of these installations, coupled with the breathing motifs in *Speaker_Forest* and *(solo)* encourage the listener to embody the human qualities of the audio and 'lose themselves' in a miniature sound world. In the context of *(duo)*, the intense feeling some people get from the 15kHz frequency explores the barrier between the natural world and the man-made one.

6. FUTURE WORK/ CONCLUSION

The research and development of these smaller sound installations are necessary and important in a few simple ways; they are typically more cost-effective, portable and are modular in essence to suit a variety of different applications. It shows that this form of spatial sound artwork can be a more sustainable stream of creating artwork in the future.

Further development along the lines of *(solo)* and *(duo)* would be to expand the scope of the project itself. Adding extra domes, amps and speakers is a clear avenue forward Another option would be to try experimenting with the size and shape of the domes to test reverberant and resonant qualities of the space and metal. Improvements can be made to the current prototypes as well; polishing each dome until it has a mirror finish.

Speaker_Forest has the potential to grow into a large-scale work. Given that the premise of the work is modular and designed for more panels to be added, the piece could expand the number of aggregate audio devices and audio channels. The sculptural placement of the panels could likewise be further explored. This could include but is not limited to adding more speakers, reconfiguring their placement on each installation or have them hanging them at different heights to acoustically activate different parts of a room.

Experimenting with speakers of larger sizes could open up further compositional possibilities, as the current frequency response of the smaller speakers sounds somewhat tinny. My current idea would be to make a speaker array of larger speakers, housed in cinderblocks which line the base of a room. Above that would hang four to eight panels of the *Speaker_Forest*. Once such application could be for small performances with live electronics.

Another opportunity for development could be through the GUI: with an increase in scope, location and placement of the panels could open up new ideas for generative composition which has been briefly explored within the Max patch. This could include, but is not limited to, developing extra functions which toggle a set number of speakers of their choice, rather than a default to all speakers. It suggests that in tandem with elements of pitch, timbre and time, the role of space in musical composition has been largely overlooked. In order to develop our understanding of sound environments and

6 'Star-Shaped Droplet Levitated By Sound', YouTube, accessed Tuesday 12th April, https://www.youtube.com/watch?v=MKMf7PCkoZQ

their impacts on musical composition, we should explore interactive spatial sound choreography further.

Ultimately I think that the creation and development of spatialised audio systems should stay as modular as possible to fit the composer's needs for multiple applications. The brief piece by Zareei demonstrated to me how keeping the installation open-ended really opens up new possibilities for immersive and intimate sound spaces that play against the architecture of any given space. I think in these three installations there is promising new ground to explore the space between intimate listening environments which cater to few, or to many. Although the musical works did not directly address the need for a 'safer space', I feel as though they successfully engaged intimate and embodied performances of my own phenomenological breath. As far as using spatial sound installation as an empathic tool, I believe that the immersive nature of the work lend themselves to more embodied experiences which are unique to the individual who engages with the work.

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REFEREED ABSTRACTS

COMPUTER MUSIC CREATION: DEVELOPING WAYS OF THINKING AND NOTATING THE MUSICAL NEEDS, THOUGHTS AND IDEAS OF CREATORS AND PERFORMERS

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ABSTRACT

What's in a score? Is there more in a score than what the score is itself, more than the score as a noumenon, as something that happens in this world, more than its intrinsic qualities and outer form? Make the invisible, visible? The score invites the artist to negotiate between notions of the map and the terrain. It invites him or her on a journey, following a path, more or less defined, but the landscape and the experience will never be exactly the same due to human and natural dynamics.

A quotation from Kathleen Coessens (2013) is the launching point for a consideration of the need to develop an ontology of notation within the computer music context. Current notational practice within computer music is individualistic, often unique to a piece, and manifest by being built around the specific needs of that composition and perhaps, in a musique-mixte context, the needs of an instrumental performing score. A survey of examples of notation in computer music from the last half century will serve to prove this point.

An exploration of the potential ontological requirements of a semiotically rich notation system argues in favour of the evolution of a language that can be commonly understood. Computer music, as a musical genre, would benefit in its accessibility–to both performers and audiences alike–from such a development, whilst a commonly adopted notation would further improve practitioners and performers ability for dialogue and discourse. Computer language (e.g. ProLogic FORTH or Basic) ontologically have sets of symbols and syntaxes that specify what is to be accomplished, in a form that both computers and their programmers can understand. So, a knowledge of the language provides computer programmers and (literate)users, an agreed vocabulary with which to share ideas, concepts and new forms of knowledge. The language is dynamic as it is continuously evolving to accommodate the changing nature of computing itself.

Using a common set of symbols, perhaps derived from both the symbols of the aforementioned computer programming languages, and from the common music notation syntax could help a computer music language semiotically evolve.

While this paper will not attempt to ascribe or propose a new notation, suggesting a direction practitioners might adopt would be a step in drawing together a vocabulary and conceptual vocabulary for a music computer language.

In musique-mixte, the current practice of recording and sharing a composition is as varied as the contexts in which we find this environment. Just what constitutes a 'score' is perhaps uncertain; - is the score a piece of paper with recognisable symbols, a piece of text, graphics, a software package or patch, or something else entirely? The notation needs of an acoustic musician performing and interacting with computer are often idiosyncratically realised - with many different forms of indication inserted within the score. While the information may be gesturally indicated (e.g. use of a foot pedal to change a parameter or scene change) or through some kind of graphic representation, rarely does the score notation include anything like the procedural information that describes how an effect or process is to be achieved.

There is also a set of electroacoustic music creations which are 'fixed' - that is, the composition is a tape or software that is 'recorded' once and that is then shared. Unlike creations that have a performative or recreative component, as in musique-mixte, notation in this context is largely purposed for analysis. As a tool, software packages such as eAnalyse or SonicVisualiser provide excellent means for the deconstruction and exposition of various layers and structural elements within such a composition. These softwares are essentially historical in their function - they visually analyse sounds that have already occurred - rather than the essential element of a score which is characterised by the affordances that are inherent within it. Within the softwares however, there is already an evolving and partially accepted set of symbols and graphics that may be adaptable.

The development of a semiotic ontology for computer music will enable a language that will permit creators, performers and musicologists have meaningful, precise discourse. It could permit the use of terms which have an agreed definition and, in an age when computer music has moved beyond the experimental and into the more mainstream of music creation and experience, provide a clarity of communication between "experts and aficionados" alike.

STATISTICAL ANALYSIS OF JAZZ IN THE COMPUTER AGE: AN INVESTIGATION OF GRANT GREEN'S IMPROVISATIONAL STYLE

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ABSTRACT

This study investigates the improvisations of jazz guitarist Grant Green using a computer-aided statistical approach. The analysis of improvised jazz has been employed in the transmission of jazz language since its early beginnings, and is still an integral part of the pedagogical process at music institutions. However, the methods used to undertake analysis have not changed substantially in the last 50 years. Brought on by increasing computational power, the computer-aided statistical analysis of jazz is a field of study experiencing considerable growth. This study uses software tools and methods developed within the Jazzomat Research Project to aid in the analysis of the improvisational style of Grant Green, focusing on the years 1960-1965. Grant Green was a prolific but under-appreciated musician during the 1960s and 1970s, and was the unofficial house guitarist for Blue Note records from 1960 to 1965. The data used for analysis will be drawn from 40 detailed transcriptions of Green's improvisations from this period of time.

This research aims to create a statistically rigorous and detailed model of Green's improvisational style with respect to a wide range of independent and dependent variables. The main dependent variables will be features of melodic and rhythmic construction. Melodic construction includes: distribution of pitch classes compared to the key of the song or chord of the moment; phrase shape; and interval size; while rhythmic construction includes: note duration; beat placement; note density; and micro-timing features such as swing ratio. The independent variables include: year of recording; time signature; key signature; the chord of the moment; tempo; section of the form; and location in the solo. Some features, such as solo length and phrase length, will be investigated as both independent and dependent variables. The analysis will also investigate whether there are distinctive patterns that Green uses, and how these may be influenced by the independent variables.

The analysis will be undertaken in multiple steps, including: descriptive statistics and univariate analysis to investigate the features of the dataset, and limit the inclusion of variables in further analysis; bivariate analysis to examine the relationships between pairs of variables, informed by prior studies; and multivariate analysis to study more complex relationships to investigate how Green's improvisational style changes under differing conditions. Due to the variety of data types present in the dataset a range of analytical tests will be employed, including analysis of variance, regression, and compositional analysis.

It is intended that the results of this research will be able to be applied in future research, including machine learning classification and generation tasks, while also extending our understanding of music and approaches to analysing improvised jazz.

ORIGINAL SIGNALS: ETHICS AND EXPERIMENTATION IN THE POST HUMAN PRESENT

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ABSTRACT

This is an anthropological report into the practice of contemporary computer music production. Its purpose is to describe how and why the computer has become so central in the creative lives of its users. It differs from other studies into computer music in that it is concerned with a wide variety of experience and aesthetics. The paper draws upon a 12-month-long ethnography into electronic music practice in Adelaide, based on participant observation and in-depth semi-structured interviews. The research has covered over 60 events, and interviews with over 50 musicians, aiming for a broad spectrum of participants based on age, genre, gender, and experience. Questions explored the practice, values and beliefs of those currently engaged in electronic music production, and the role of digital technology in self- representation around music. By focusing on a demographic attuned to current trends through participation in a competitive cultural industry, combined with the experimentation that is a part of finding one's own creative expression, it was hoped this social group would be ideal for accessing contemporary attitudes to our relationship with technology.

This paper has two aims. First, it shows how aesthetic performance seeks to accommodate a highly individualistic ethical attitude. In her ethnography of cultural production at the BBC1, musician and anthropologist Georgia Born, identified how the aesthetics of performance always reflect the ethical orientation of the producer2. Against a background of global influences, local contexts and media infrastructures, where the center of the action is increasingly open to question, the infinite possibilities of digital technology are attractive for the expression of a complex contemporary subjectivity of interaction and relationality.

Secondly it presents three case studies that illustrate how the accessibility of musical experimentation afforded by the computer can synthesize personal development with virtual possibilities. With social media a live feed of what is happening culturally throughout the world, my participants input from a spectrum of influences, transforming them through accessible software platforms, often producing works designed to reject comfortable classification.

An attitude of experimentation, allied to ethical values, characterizes this performance politics of the personal.

This paper also has a theoretical function, to test the claims of posthumanist writers, who champion a move away from the rigid definitions of human, nature and machine, into an altogether new assemblage where such boundaries become open to question. Rosi Braidotti envisions a new cosmopolitan humanism emerging3, "drawing energy from the thinkability of the future...an active transposition, a transformation at the in-depth level, a change of culture akin to genetic mutations, but registered also at the ethical level."4 The paper asks how computer music practice may act as an indicator of what we may be in the process of becoming?

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DIRECTING GEOMETRIC MUSICAL REPRESENTATIONS WITH CURVE-BASED METAPARAMETERS

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ABSTRACT

Creating adaptive music for video games presents a number of challenges to composers. Herber draws a connection between composition practices found in open form works (2008). However videogame soundtracks which adapt to their environment cannot rely on a human's musical agency in order to perform a rendition of a work. As such to process of the work must address elements of performance in far greater detail. To address these issues this research has developed a representation of symbolic music derived from Tymoczko's (2010) developments of Lewin's theories of Generalised Intervallic Spaces (1987). This representational framework provides a vector based representation of intervallic spaces which facilitates the use of spatial functions such as curves to direct movement in the intervallic spaces. By utilising spatial representations of metaparameters, the musical structure can be planned and followed, allowing for direction in musical features. However the plans can be changed and altered at any point without losing the current context. This capacity to relate any current context to any new context provides great potential for real-time adaptive systems, such as an adaptive music system in a videogame engine.

This paper will provide an examination of the affordances availed to a composer though the manipulation of metaparameters to direct a metacreative system. Practical examples will be provided with a prototype system which implements the processes and representations outlined above. The system is designed to explore these concepts within the context of an adaptive music system for video games. These examples explore mapping pitch curves to structural tones in the creation of a phrase in a musically sensible manner.

Additionally maintaining continuity across changes in pitch and metrical structure are explored. This process allows for the directing of key structural pitched elements of a work while maintaining the agility to adapt to new input. The results of this system will be reported as the complete artifact in the form of the system's output and in both visual representation and symbolic score based means so as to provide the best platform for discussion of the quality of the system and by extension the affordances of the techniques which it relies upon.

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DOPPELGANGER: ANALYSIS AND REFLECTIONS UPON A MULTI-PERFORMER, MULTIMODAL WORK FOR UNENCUMBERED WIRELESS WEARABLE SYSTEMS

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ABSTRACT

This paper examines the creative process and thinking behind new multi-media performance work Doppelgänger. The work examines the use of multiple unencumbered wireless performance interfaces to drive multiple media elements in the performance. The performers simultaneously perform lighting and music elements using free arm and hand gestures. Performer one controls an intelligent light system that moves theatrical lights and changes light parameters in response to the performer's gestures, while performer two controls the music elements in a similar way.

The body and choreography are at the centre of the work and the work explores a number of questions:

• What correlations or congruities form in terms of the gestures of the two performers responding to and in the case of the second performer also controlling elements of the music.

• What correlations are there between the media elements and how does motion and spatiality in particular relate between the body, lights and music?

• How do the bodily gestures relate to and inform the mapping relationships of both media elements?

• What, if any, hierarchies emerge between the different media throughout the composition process.

• What role do metaphors play and what audio-visual metaphors exist in the work?

The paper draws upon multi-modal analytical techniques, with a particular focus on the Interacting Cognitive Subsystems (ICS) model of cognition developed by Phil Barnard. This model will be applied to the development of Doppelgänger in order to explain some of the creative and intuitive decisions that were made during the creative process.

REAL OR VIRTUAL? REVEALING CULTURAL IDENTITIES THROUGH HETEROTOPIAN CONSTRUCTS IN MUSIQUE-MIXTE

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ABSTRACT

This paper presents a discussion of performative heterotopia within musique-mixte. Heterotopia is proposed as a performance space of connectivity; of interwoven perspectives of experience and practice; and of multiple modes of interaction. Electroacoustic elements of performance are proposed as enablers, as mediators for cross cultural understandings in performance, and the negotiations and relationships created within the space that converge as a shared experience of cultural diversity.

Nicholas Bourriard recounts in his introduction to Michel Foucault's Manet and the object of Painting (2009) that Foucault developed the concept of 'heterotopia' as a way of representing "a constant among all human groups, [which] can be described as 'anti-location'". It consists of an ensemble of "places outside of all places, even though they are at the same time localizable" (Bourriaud, 2009/11). The concept of an ensemble of places expands into heterotopian performance spaces where the performance may articulate diverse relationships and interactions through the integration/juxtaposition of acoustic and electronic elements. Foucault's heterotopias have several main principles: they are a feature of all cultures and societies; they are capable of juxtaposing several spaces within one; they are connected to a slice of time; they assume a system of opening and closing; and, "they have a function in relation to all the space that remains - either to create a space of illusion that exposes every real space, or, to create a space that is other, another real space" (Foucault, 1986). These ideas are here transferred to the music performance space construct and intercultural experience.

The research project, The Imaginary Space: Developing Models for an Emergent Malaysian/Western Electroacoustic Music (Malaysian Government Fundamental Research Grant Scheme 2012-14) (Penny, 2015), aimed to make artistic and cultural connections through the medium of musique-mixte, to experience contemporary and traditional music practices of Malaysia and to examine aspects of cultures and interculturality in a context of new electroacoustic composition and performance. New compositions utilized Western flute, fixed sound and live electronics. It was found that creating a sonic environment through the digital signal processing provided a context for investigation of intercultural parameters and the potential for creative exchange. The capacity of electronic techniques to shift perceptions of sonorities, location, spatial dynamics and characters of the music challenged listener and performer expectations and responses, provoking shifts in understandings and performative identities, and activating new interchanges through a fusion of practices and cultures.

This paper extends the investigation of heterotopian perspectives of this work from the perspective of the flautist. Synthesis and divergences of timbre are investigated through aesthetic and sonic characteristics of serunai, pensol flute, concert flute, Uthmani recitation and DSP – juxtaposing cultures and space. Consideration of dominance and responses of volume include saturation/minimization of electronic sound, micro-sounds and multiplication, and aspects of distance and proximity relate to Foucault's opening and closing of the space. Shifts of cultural identity and new understandings emerging within the temporal in situ performance (Foucault's "slice of time") are described from the inside, the living experience of negotiating distinct musical and cultural behaviours. In addition, the question of whether these exchanges were grounded in the real or virtual is visited – were they illusions or reality?

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THE COMPETITION: INDIVIDUALS AND SOCIAL STRUCTURES WITH MUSICAL AI

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ABSTRACT

This project is a listening room installation that treats multiple instances of neural networks as individual agents, and explores emulating 'social structures' to refine solutions to musical problems. Populations of 'individual' agents are organised into various groups such as a panel of judges, bands, and an audience. These groups will refine a 'best' possible solution, live, for specific physiological challenges defined beforehand.

This installation was not the original aim of the research project that gave rise to the agents. Originally neural networks were created and trained using a music algorithm and a physiological feedback from a selection of human participants to drive the algorithm 'solo' for composition tasks (links to examples are included). Due to the large numbers of variables involved and the broad range of responses from the participants, the confidence of the networks is typically short of being mathematically satisfactory for any strong conclusions which is fairly common in affective algorithmic composition systems (Williams et al. 2014).

However, for musical/creative agent outcomes this is satisfactory, as it is difficult to argue that any musical structure is „incorrect‟ for any given purpose. It was found that the training process of these neural networks led to situation where each instances could contribute unique but technically „correct‟ musical solutions to an affective target with similar confidence, leading to the conclusion that these networks had unique approaches to interpreting the reactions of humans to changing musical structures.

An affective challenge will be set requiring a musical passage which can attempt to provoke a particular physiological reaction in humans as a solution. The agents are arranged into three groups. First is the panel of judges, best trained of all the agents, and prone to mild audio gestures. The second is the bands themselves, who perform generated pieces. Third is the audience, who provide approval or disapproval as applause, yelling, and other gestures. These don‟t affect the songs generated, but have a chance to influence the judge‟s decisions. While all the agents are trained using the same data and architecture, the nature of training neural networks imposes unique results for each agent, which informs their respective decisions.

The public will be welcome to enter the listening room and listen to the progress of the competition using a small surround sound PA or binaural headphones. The bands will play towards a winner for the duration of the time allotted, and the best scoring pieces will be combined into one piece, and can be presented at the end of the conference either online, and/or in a short presentation.

Algorithmic affective works for piano generated using similar agents can be heard via the following links:

https://soundcloud.com/danpitman/searching-for- machine-the-affective-algorithmic-composer

https://soundcloud.com/danpitman/good-vs-evil-the- affective-algorithmic-composer

https://soundcloud.com/danpitman/moments-in-the-mathematical-forest-the-affective-algorithmic-composer

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REJECTING POST-HUMANISM, HUMANISM AND ANTI-HUMANISM; WHAT COMES NEXT?

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ABSTRACT

Implications of Malabou's and Badiou's contemporary accounts of subjectivity.

Watkin recently claimed, “French philosophy today is laying fresh claim to the human” which constitutes “a series of fundamentally independent and yet strikingly simultaneous initiatives arising across the diverse landscape of French thought to transform and rework the figure of the human” (Watkin 2016, 1). If we follow Watkins, the least partial way to characterize the recent trajectory of contemporary French thought is a rejection of both the conceptual division between humanism and anti-humanism and the discourse of post-humanism—that Watkin calls “beyond the trichotomy” (2016, 2). Instead, in the wake of humanism, anti-humanism and post-humanism, Watkin sees “new figures of the human” (Watkin 2016, 1) present in the positive projects of Serres, Latour, Meillassoux, Badiou and Malabou. The schema of ‘beyond the trichotomy’ is a useful way to characterize these philosophical projects that distance themselves from the linguistic paradigm of deconstructionism and phenomenology. However, unlike Watkins, I will argue that a more conceptually rich way of thinking about these projects is through the lens of exceeding finitude that defines the subject outside of Watkin’s trichotomy. What comes next? New visions of subjectivity.

What are the consequences for music? Of this group, Badiou is the only philosopher to have ventured an answer to such a question. This paper explores initial ideas in this direction.

REFEREED PERFORMANCE WORKS

HUSH! CAUTION! ECHOLAND!

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ABSTRACT

Hush! Caution! Echoland! is part of a series of works entitled "Sounding Finnegan's Wake". In this series computer/algorithmically generated instrumental, acousmatic, interactive, and audio/visual pieces are being developed, based on the sound and structure of Finnegan's Wake . The premise informing these works is that Finnegan's Wake can be understood as a textual work and as sound art. In Joyce's writing these two approaches are complementary, each informing and influencing each other. Hush! Caution! Echoland! takes chapter one of Finnegan's Wake as its material, from which to create a score for traditional instruments and electronics. The instrumental part is derived from the structure of the text as expressed initially through its ASCII representation. This is then deconstructed through a number of processes to form the score for Flute, Clarinet, Violin, Viola and Cello. The electronic part also uses the ASCII representation of the text and spatializes the instrument sounds according to that structure. This is done through use of synthetic reverberation and panning techniques. Processes for using text to generate music have been explored by many, including the author, and the outcomes are varied. These processes range through an aesthetics based text setting, such as the writing of a pop song or liturgical music where the compose a response to what they they think complements the text or and answers the intentions of the author. Other approaches, such as using the inherent sounds of the text are comparatively rarer. Brunson's [1] discussion of processes is comprehensive, and Eberhard Blum's [2] renditions of Cage's Mesostics re Merce Cunningham and Amanda Stewart and Chris Mann's [3] works are indicators of taking text from the descriptive realm to the less descriptive realm of sound art are examples. Processes for using text as a system for musical creation that is not designed to represent the meaning of the text are even rarer, the author has explored this [4-8], and this project is a continuation of these explorations. Work by others in the area is varied across a wide field ranging through exemplars ad processes [9- 15]. Details of the processes use will be discussed in the accompanying 'Piece and Paper'

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GENERATION 2

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ABSTRACT

Generation II is an interactive electronic music performance between a live improviser and the ‘Evol’ algorithmic music system. The work explores the premise that musical structure can arise from variations and elaboration of musical motifs. The work explores the automation of these process in the iterative improvised context of performance with a live algorithm.

This work continues the artist’s exploration of performing with reflexive music software where the musician’s performance is captured and fragments are transformed and re-used as part of a generative musical accompaniment (Gifford and Brown 2011; Brown, Gifford and Voltz 2016). In particular, the Evol system transforms the captured fragments over time, using them as motifs on which to elaborate. In Generation II multiple software agents using the Evol system create a layered texture that transforms in subtle ways over time. The agents are synchronised by an underlying time base. The effect is often reminiscent of the works of minimalist compositions from the 20th century.

Interaction between the performer and algorithmic music system is primarily via the performance itself. The Evol system includes real-time analysis of the performance and does feature extraction that guides the generative response. In addition, some direct performer control of the software agent behaviour is possible via a gestural interface.

The Evol system is MIDI-based and so the timbral character of the work is determined by sound choices in the playback engine. In the performance of *Generation I* these were tonal analogue synthesizer tones, whilst for Generation II these will be mixed with more aggressive glitch and noise based timbres.’

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MOSAICS AND TRANSPARENCIES

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ABSTRACT

Mosaics and Transparencies (2017) is a multichannel live electro-acoustic improvisational algorithmic composition that consists of a number of diverse sound recordings mixed and performed live over a multi-channel loudspeaker system.

The sound recordings are each 1⁄2 hour long, and any portion can be played as part of the mix. They consist of algorithmic mixes of up to 61 samples arrayed in time so that each sample occurs only once or twice or three times during the 1⁄2 hour duration.

The samples consist of a number of kinds of sounding material, each featuring lots of silence as well as sound:

1) Electro-acoustic sounds recorded with contact mics attached to a wooden resonator on which acoustic objects are placed. (Homage to Pauline Oliveros's "Applebox" series of pieces).

2) Riffs in microtonal scales played by samples of non-Western musical instruments (the UVI World Suite) controlled by the algorithmic generators in Joel Kivela's "Dhalang MG" program (Markov Chains, Physical Models of gravity/bouncing systems)(an homage to Ervin Wilson).

3) Sounds generated by converting a series of several hundred drawings made by hand over a 10 year period into sound, using 2C Audio's "Kaleidoscope" program. The partials of each sound are tuned into a different microtonal scale.

4) Samples of long individual tones played by samples of Western orchestral instruments (Spitfire, Garritan, VSL) modified by a wide variety of sound modification programs.

5) Acoustic recordings of various environmental sounds treated in a musique concrete manner.

6) A collection of short gestures made with analogue and digital synthesizers. Most are tuned to a wide variety of microtonal scales.

There are several different recordings of each of these kinds of sound materials, each one featuring a unique set of sound samples. These sound-type recordings are then mixed into a 1⁄2 hour composite recording, which while thicker in texture, still has substantial amounts of silence in it.

This collection of recordings is then mixed live into a sound-routing system, featuring as many channels as are available.

EHOJ ELOCIN

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ABSTRACT

Nhoj Elocin is a collaboration of John Ferguson and Nicole Carroll. This project explores improvisation with lively and semi-autonomous processes in surround-sound environments using custom software and self-made instruments. While tactile interfaces are considered vital, algorithmic complexity provides a catalyst. Performed and captured via four speakers arranged in quad, Nicole's diffusion system affords exact but idiosyncratic spatialisation of sound, and she take overall responsibility for the placement of both artist's sounds in space. The overall agenda is to traverse noise aesthetics, contemporary computer music, and the repetitive rhythms of groove-based pop forms.

John performs with Mobile Noise Rig (MNR), this is a handmade instrument built around a Teensy microcontroller and an iPad. MNR features arcade buttons for tactile responsiveness and visual feedback, as well as a bend-sensor equipped hole-punch that underlines the potential of everyday and often-overlooked mechanisms. Bespoke software combines granular sample-mangling with lively approaches to vernacular rhythm and groove. Pseudo-random and generative processes place notions of 'imagined-agency' at the foreground. All of the MNR software runs on an iPad via Mobile Music Platform

(MobMuPlat). John's pseudo-anthropomorphic practice raises issues of causality, agency and legibility. MNR foregrounds the question: are we performing the technology or is it performing us?

Nicole performs with the Byzantine controller, which utilizes capacitive touch sensors on a circular grid (modelled after a Byzantine chessboard) that visually mirrors a surround sound configuration. The goal in developing this controller is to help merge the performance aesthetics of acousmatic diffusion with that of hacked electronics. Audio from homemade analog circuits is sent to Max/MSP, where pitch and amplitude tracking in conjunction with chance procedures control processing parameters. Chance procedures are driven by tarot card relationships and numerology as the software "draws" cards during performance. Direct and ambient light actuates a master circuit, ensuring a degree of uncertainty. The agency of the system–the machines in combination with chance procedures–prompts a responsive approach from the performer.

KAPS FREED

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ABSTRACT

This work aims to bring the sound of the piano as close as possible to the sound of Percy Grainger's Free Music ideals, using pitch tracking and spectral filtering. It aims to transform the sound of the piano as closely to the Free Music ideal as possible, by sampling its pitches and transporting them into theremin like tones where the tempered scale becomes irrelevant.

The 'Kaps piano' is the childhood piano of Percy Grainger, and lives in the Grainger Museum in Melbourne. It was made in Dresden, Germany in 1887. Percy practiced on this piano for two hours daily as a child, presided over by his teacher and mother, Rose Grainger. I have always been fascinated with Grainger's Free Music, and this work explores the link between his childhood practice routine and lessons with his later investigations into Free Music. This was a music characterized by the emancipation of rhythmic processes and pitch, both explored in this, and most of my, work. The piano part is my response to the same lake, Albert Lake in Melbourne, that is said to have been the inspiration for Grainger's theory of Free Music whose family were also students of Rose's, bought the piano from the Graingers, and kept it for forty years before donating it to the Grainger Museum in 1935. It is now on permanent display at the Museum.

Each colour represents a finger on each hand. The blue shades being the right hand, the red shades being the left. Use the sustain pedal to keep the notes ringing as long as possible.

A grey dashed line shows middle C for reference purposes. A thinner grey dashed lines assist to show when notes remain the same pitch.

The electronics part is indicated in opaque parts. This samples the piano at different moments, turning the piano tone into a sine tone (like a Theremin tone) and the colour represents the 'hand tonality' to be sampled at the moments marked on the score.

The score should be read in the Decibel ScorePlayer application on an iPad, or as a video score.

http://www.cathope.com/kaps-freed-2017.html

GOYDER'S LINE

Tristan Louth-Robins
Independent Artist
Adelaide

ABSTRACT

"The plains that I crossed in those days were not endlessly alike. Sometimes I looked over a great shallow valley with scattered trees and idle cattle and perhaps a meagre stream at its centre. Sometimes, at the end of a tract of utterly uncompromising country, the road rose towards what was unquestionably a hill before I saw ahead only another plain, level and bare and daunting." Gerald Murnane, The Plains.

The plains surrounding the ghost town of Dawson are situated in the lower Flinders Ranges – a vast arena of ochre-coloured earth and sparse vegetation. The presence of distant hills that stretch around the plains appear to reinforce the utter stillness of this place. As if time and motion are suspended or are just inclined to unfold at their own pace. As one spends more time in this place, its unique properties are revealed. A subtle scent carried on a breeze that sends a rustle through dry leaves, the droning buzz of busy insects, the brief relief that lies in the shadows of clouds drifting slowly over the terrain and discrete rumbles that exist just on the audible periphery.

Sometime during 1865, a few kilometres south of where Dawson would be settled twenty-three years later, George Goyder was travelling across the region on horseback. Goyder, who was the South Australian colony's Surveyor-General had been tasked with the duty of mapping the boundary between areas that received regular rainfall and those that were prone to drought. Based on Goyder's Line of Rainfall and the subsequent report detailing his findings, farmers were discouraged from planting crops north of the line. In most instances, this advice was not heeded.

At the beginning of the 21st Century as much of Australia was enduring the Millennium Drought (1997-2009), Goyder's Line became a point of reference for meteorologists, climate scientists and farming communities. During the drought it became evident that the line of rainfall as identified by Goyder in the late 19th Century - whilst being subsequently regarded as a highly accurate tool of analysis and agricultural planning for most of the following century - was requiring reassessment and pointed to a southward trend in light of protracted drought, shifting seasonal rainfall patterns and the impact of anthropogenic climate change.

Goyder's original line of rainfall and a recent 21st Century revision inform the basis of this electro-acoustic work. The lines - their relative patterns and trajectories- represent the fundamental frequencies of two sawtooth waves, which are routed as inputs to a vocoder and extended effects modules. Although each of the frequencies remain distinct throughout the work, the resulting modulations reveal expansive sonorities and rich harmonic textures. At regular iterations the lines are purposefully suspended in parallel, allowing their harmonic relationship and modulations to unfold and develop.

I regard this work as an ode to the South Australian interior, as defined by Goyder's original line and its contemporary revision. The interior, at its boundary appears as a vast, seemingly boundless space - rich with the possibility of uncertainty, terror and fascination.

BERING(FORBODING)

Cissi Tsang
School of Music
Edith Cowan University

ABSTRACT

Bering(forboding) is an audiovisual piece created from a combination of field recordings and data taken from field footage. Bering(forboding) is an example of using multiple data elements in the composition process, and using data elements as methods of conveying narrative through the creative interaction between composer and data.

The creative process behind this work involves the use of data structures as ways of driving sonification and compositional processes, through collected digital media and computer-assisted composition. The work is also intended to explore how the visual and aural can be used to influence the other within the creative process. For Bering(forboding), the initial field footage and recordings were taken from a night spent at Beringbooding Rock, roughly 360km north-east of Perth.

To create the audio track, values from a histogram showing the red, blue, green and luminance channels of a photograph were converted into sound frequencies, and these frequencies were combined with a series of layered, progressively time-stretched recordings (between 200% - 1600%) of a crow recorded in the same area. Three vocal tracks from the composer were also added to this composition, and the finished audio track was used to drive a musical visualisation where audio frequencies were used as keyframes for the animation movements.

With this practice, the visual and aural are linked through a combination of sonifying digital information taken from digital documentation, and using aural information (via combining field recordings with compositions created from various methods of sonification) to re-create visual information through the use of music visualisations.

LINES OF FLIGHT

Lindsay Vickery
Western Australian Academy of Performance Arts
Edith Cowan University

ABSTRACT

Implications of Malabou's and Badiou's contemporary accounts of subjectivity.

This is a nonlinear work for clarinet and synchronized electronics. It comprises 23 sections of musical material that are presented indeterminately to the performer and a coda. The scrolling-score is presented on iPad and controlled externally from a laptop. Sound processing involves an array of delays, pitch shifts, spectral manipulation and down-sampling.

The title refers to Deleuze' concept that "Multiplicities are defined by the outside: by the abstract line, the line of flight or deterritorialization according to which they change in nature and connect with other multiplicities. The plane of consistency (grid) is the outside of all multiplicities. The line of flight marks: the reality of a finite number of dimensions that the multiplicity effectively fills; the impossibility of a supplementary dimension, unless the multiplicity is transformed by the line of flight; the possibility and necessity of flattening all of the multiplicities on a single plane of consistency or exteriority, regardless of the number of dimensions."

REFERENCES

PERFORMANCE WORKS

Short Abstracts

TRANSIT

Brigid Burke
Independent Artist
Melbourne

ABSTRACT

TRANSIT is about the stillness of the Lane ways of Melbourne in the early hours of the morning layered with a riot in the centre of Florence. The music/visuals depict the streets, people moving through both cities architecture and city scenes. TRANSIT explores connections with the present histories within the two cities and musical influence and the importance of colour painting, electronic beats, layered soundscapes and light to create a linkage between the two cities.

BLAGOVESHTENIJE

Robert Sazdov
Creativity and Cognition Studios
University of Technology Sydney

ABSTRACT

BLAGOVESHTENIJE 07.04 (2013/17, ACMC 2017 version) is the third and final composition of a trilogy that consists of Bogorodica 28.08 (2005) and Deva 21.09 (2009), which addresses important dates in the Orthodox calendar attributed to the Mother of God. As with the other compositions in the trilogy, Blagoveshtenije 07.04 incorporates both sacred and secular influences. Various traditional instrumental timbres and rhythms, along with Macedonian Byzantine vocal manipulations form the sonic basis for the work.

The spatialisation approaches used in the composition are based on psychoacoustics and perceptual research undertaken by the composer. The ACMC 2017 version is an 8-channel version of a 40+ channel composition premiered at ICSA 2015 in Graz, Austria. Various spatialisation techniques have been employed to generate the perception of height within a horizontal loudspeaker array.

ON THE PHILOSOPHICAL IDEA OF THE BEAUTIFUL

Scott Simon
Creativity and Cognition Studios
University of Technology Sydney

ABSTRACT

This piece is part of the artist's research in relation to working between music and philosophy. The structure of the works is a 3 part artifact comprised of textual and music components. The piece consists of improvised guitar and interactive electronic soundscape. Ableton Live is utilized with various custom built Max 4 Live applications. The guitar work is amplified though an Avid Eleven Rack that runs into an audio channel on Live. A screen with the "program" text and imagery is also part of the work.

The performance is organized around the artist's research, focusing on the human gesture as a component that is not "replaced" by algorithm but which plays its part in forming the algorithmic component. Further, the improvisatory style in relation to the guitar is altered and "re-tooled" to accommodate the new computational forms. The "new forms" are structured in relation to philosophical metaphor.

The forms are blended-space structures that consist of:

(1) philosophical ideas about beauty, and;

(2) musical expression.

RECYCLE+SHUFFLE+REPEAT

Mark Zanter
School of Music
Marshall University, USA

ABSTRACT

Recycle+Shuffle+Repeat (2016) was commissioned by oboist Dr. Richard Kravchak for his U.S. tour 2016. The work recycles material from Homage (2014) for oboe and string orchestra and a FM synthesizer built in Max/MSP. Shuffling processes were applied at various levels working in conjunction with repeat, which was applied mainly to larger proportions using composer generated procedures.

Clarinetist Brigid Burke, of Melbourne will premiere the clarinet version of this work.

UN-REFEREED ARTIST TALKS

Abstracts

Luke Harrald
Elder Conservatorium of Music
The University of Adelaide

ABSTRACT

This presentation explores 'Macau Days', a collaboration between John Young (Artist), Brian Castro (Poet) and Luke Harrald (Composer / Sound Artist). An interdisciplinary gallery installation and tri-lingual book, the work incorporates a range of cross-sensory materials that respond to the rich and eclectic history of Macau; its mythical figures, culture, music, literature and cuisine.

The sound installation for the work draws on Harrald's previous body of work that aims to shape our perception of place, and sense of Dasein - or "being there" - through offering an audience experience that blends real and composed sonic environments, and constantly shifts the listener's sense of perspective within the diegesis of the work. The boundaries of diegesis in electro-acoustic music are often more difficult to define than in traditional western music due to the relationship the recorded materials have with everyday sounds. In sound installation works, this ambiguity is advantageous as it draws the listener in to relating the sound materials presented within the space with their own previous experiences.

Macau Days takes a particularly innovative approach to audio spatialisation, incorporating a quadraphonic surround system and three Holosonic panels mounted above the audience. The Holosonic panels create three columns of sound within the overarching surround mix. As the work is based on six poems by Castro, that are published in three languages, this approach allows for the simultaneous presentation of the poems in English, Portuguese and Mandarin.

Christopher Williams
Independent Artist
Adelaide

ABSTRACT

The materialisation of sound as audio recording opens the potential for operations to be carried out on sounds: editing, montage, signal processing, mixing, sequencing, etc. Pierre Schaeffer practised an empirical method of composition, composed listening or composing by ear. This marks it as related to oral traditions rather than the literate. Friedrich Kittler notes that the typewriter objectified the word onto the page as a fixed medium. With the word processor that medium became virtual and flexible, allowing for the playing with montage techniques first developed for cinema. Using the metaphor of writing with sound, one can draw an analogy between empirical composition with sound objects and literary text production in the age of the DAW.

Literary text production theory offers a number of concepts useful for empirical composition: dialogism; heterophony; intertextuality included; and offers ways of understanding how sounds are rendered semantically meaningful. Glenn Gould (montage music); Mauricio Kagel (musicalization of speech); and Stockhausen (music approaches speech: speech approaches music) explored these dramaturgical relations in their speech-based composition and sound studio production.