Seeing the inaudible, hearing the invisible

Proceedings of the Australasian Computer Music Conference 2019
Hosted by The Sir Zelman Cowen School of Music - Monash University.

23rd to 27th July 2019

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Proceedings of the Australasian Computer Music Conference 2019, Melbourne, Victoria

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With special thanks to:

The Sir Zelman Cowen School of Music at Monash University,
Published by The Australasian Computer Music Association.

http://computermusic.org.au

December 2019 ISSN 1448-7780

Proceedings edited by Lindsay Vickery.
All correspondence with authors should be sent directly to the authors.
General correspondence for ACMA should be sent to info@computermusic.org.au

The paper refereeing process is conducted according to the specifications of the Australian Government for the collection of Higher Education research data, and fully refereed papers therefore meet Australian Government requirements for fully-refereed research papers.

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HEXANY DIAMOND 5 7 11 13
A POLYRHYTHMIC, POLYTIMBRAL, MICROTONAL FIXED-MEDIA COMPOSITION

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ABSTRACT

"Hexany Diamond 5 7 11 13" is a 10-minute long fixed-media composition made with Wide Blue Sound's "Orbit" sample-playback synthesizer, living inside Native Instrument's Kontakt sampler. The piece is tuned in a scale derived from the work of Ervin Wilson, a 19 note scale called a Hexany Diamond, based on harmonics 5, 7, 11, and 13 (Narushima 2017). This paper discusses the software used for the composition, the patch, methods of performance, and the structure of the composition.

1. INTRODUCTION

"Hexany Diamond 5 7 11 13" is a 10-minute long fixed-media composition made with Wide Blue Sound's "Orbit" sample-playback synthesizer, living inside Native Instrument's Kontakt sampler. Three instances of Kontakt live inside Plogue Bidule, each with their own Step Sequencer, to provide polyrhythmic playback. This setup is performed interactively with a control panel set up in Algorithmic Arts' MusicWonk. The piece is tuned to Ervin Wilson's "Hexany Diamond 5 7 11 13" scale, a 19 note just-intonation microtonal scale, made in Marcus Hobb's "Wilsonic" app. In this patch, "Orbit" can play 4 microtonally-tuned pitches at any one time. Two passes of the patch are recorded, which, in total, play 18 pitches of the 19-note scale. The piece features polyrhythmic alternations of Orbits 4 sample players, building up to an 18 note cluster near the end.

2. ORBIT - THE INSTRUMENT

Orbit is a sample-playback instrument from Wide Blue Sound of Los Angeles. It is one of a number of recent sample-playback systems that feature more complex pre-made samples in an effort to assemble more complex timbres than simple analogue synthesis or acoustic-instrument playback. Other examples of this kind of synthesizer are "Infundibulum" from Sound Dust, "Kepler Orchestra" from Spitfire Audio, and "Cataract" from Glitchmachines. Living inside Kontakt, Orbit has four sample players. These four can play back from a library of over 100 fairly long samples. Each of these samples features some kind of sonic evolution. Each sample player can be tuned precisely, filtered, panned, etc. Any selection of the four players can be alternated between with three different transitions – different

Figure 1. Wide Blue Sound: Orbit Sample Player

envelopes used to cross-fade between the players. The rate of these transitions is also controllable, either with the on-screen control, or with an external MIDI modulator. A "depth" control will allow the players to fade from alternating envelopes to constant playing. Figure 1 shows the user interface of Orbit.

The sounds made by Orbit all feature a kind of sonic evolution. Even the basic sine-wave-like timbre, called "Pure," has a changing spectrum over time. Other sounds such as "Shimpering" have more pronounced harmonics, but less long-term sonic evolution. Each of the over 100 sounds available in Orbit has some kind of sonic evolution and each is at least 20 seconds long. Most of the sounds, despite their evolution, still have a sense of being centred on a pitch, with focus on a more or less harmonic spectrum. Wide Blue Sound has another unit, with the same interface, but with a different set of samples, many of which are more "texturally" oriented rather than pitch-centric. This synth is called "Eclipse." With four sample players, one can alternate between up

to 4 different timbres. The kind of envelope used for the transitions, from sharp (sawtooth or square wave envelopes) to smooth (sine wave envelopes). The speed of alternation can also be changed in real time. Further, the depth of this alternating envelope can also be changed. With "depth" set to 100, the four waveforms are heard as distinct sounds. With depth set to 0, then all four waveforms are heard as a sustained poly-timbral chord. Further, the pitch of each sample player can be microtonally detuned by cents to a tolerance of 2 decimal points. So a typical sound on Orbit can involve alternating between four different evolving, differently tuned samples. The speed of alternating of the timbres can be changed, as can the depth of the alternation, up to all four timbres being heard together in a sustained polytimbral microtonal chord.

3. THE PATCH FOR EACH OF TWO PASSES

The piece was made in two real-time passes, each using the same patch, but with different timbres and tunings for each pass. Two patches were used and they are shown in Figure 2. The real-time performance interface was made with Algorithmic Arts "MusicWonk," and the overall patch was made with Plogue's "Bidule." The MusicWonk controller patch (top) has an on/off switch for everything, then three sliders, one each for "Depth" on each instance of Orbit, then an alternation envelope setting for each of the three Kontakt instruments, then three speed selectors, one for each of the three Orbit's alternation speeds.

The Plogue patch (bottom) has a MIDI in (from MusicWonk), three Step Sequencers (one for each of the three Kontakts, the three Kontakts, and a mixer and output. Each instance of Kontakt has a different version of Orbit, each micro-tuned to a different microtonal chord, and has a different selection of timbres. The three step sequencers continually change tempo between 20 and 240 bpm independently, producing polyrhythms. These are controlled by three sine-LFOs in MusicWonk.

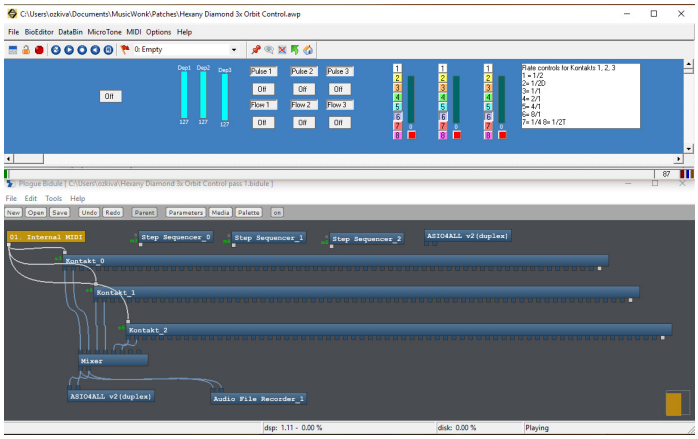

Figure 2. (top) Real-time controller interface made with MusicWonk. (bottom) Overall patch for each pass of the piece made with Plogue Bidule.

3.1 Controlling the Speed of the Alternating Timbres

In Figure 3, in the top of the Kontakt player, you see a window called Sync. In this, Step Sequencer 1 is selected. At the top left, you see Step Sequencer 1 open. It continually varies between 20 and 240 bpm. This means the alternating of the timbres between the four sample players in Orbit is continually accelerating and

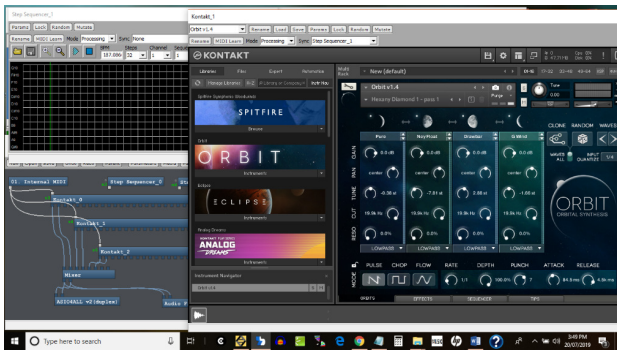

Figure 3. The connection of the MIDI step sequencers to the Kontakt Player for real time control of alternation speed between the separate timbres.

decelerating. With three of these going independently, quite complex polyrhythms are generated. In fact, with three generators using different tempi changing between 20 and 240 bpm, and the rate of acceleration and deceleration of the three tempi all proceeding at different rates, the polyrhythms are beyond my capability to predict, or describe, and this is a kind of irrationally relating rhythms that I have been assembling, and learning how to listen to since at least the early 1970s. With the two passes of the patch mixed together, 6 different tempi of alternating timbres are heard simultaneously. Occasionally, the Depth controls on the Orbits are moved to 0. This makes a sustained chord of the 4 pitches in any instance of Orbit. At about 8 minutes in, all the Depth controls are moved to 0, making a very thick microtonal chord.

4. THE TUNING

This piece uses a scale based on the work of Ervin Wilson.

Figure 4. Ervin Wilson, 2010. Portrait by Catherine Schieve.

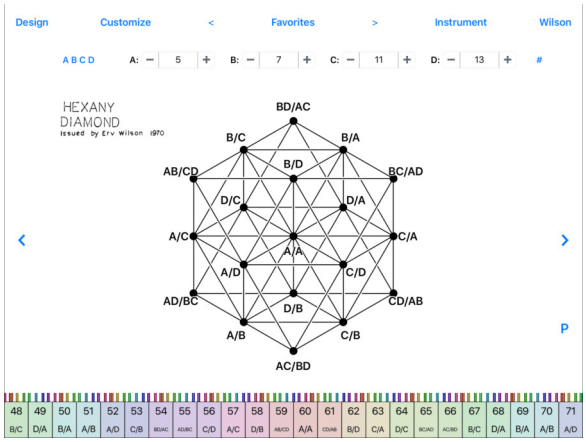

Figure 5. Hexany Diamond page from Marcus Hobbs' Wilsonic iOS app.

Ervin Wilson (1928-2016) was a music theorist in Los Angeles. Student of Harry Partch, he extended just intonation (and other) tuning ideas. The Hexany is a 6 element Combination Product Set featuring tuning ratios made from all combinations of 2 elements out of 4. Usually these are numbers of harmonics. A Hexany Diamond is made of the initial Hexany, plus its inversion, plus all 6 possible ratios made from all the 2 element products of the set. Plus a 1/1 central tone from which all the other pitches derive. This makes a 19 note scale. Figure 5 shows the Hexany in Marcus Hobbs free Wilsonic iOS app.

4.1 The Hexany Diamond used in this Piece.

Since a Hexany Diamond is made of operations on 4 factors, usually harmonics, absolutely arbitrarily, I took 4 prime-numbered harmonics, 5, 7, 11, and 13. I used prime numbers to make sure that there were no harmonic duplicates in the scale. Apart from that, they could be any set of four prime-numbered harmonics. In other pieces of this set "Hexany Diamonds and Others (2019)", I used other sets of prime-numbered harmonics to make different scales for those pieces. I take my cue from Stefan Wolpe, with his essay "Any Bunch of Notes," in which he maintains that any arbitrary collection of pitches can be used to make a composition – one then finds the relationships resulting from one's arbitrary decision and works with those (Wolpe, 1982). Using the chosen four factors, make a Hexany out of these, using all the ratios of any two elements out of the 4 given. The following lines show how the ratios are derived from each set of two elements from the four given harmonics. The final line shows the 6 pitches of the hexany in cents.

A/B = 5/7 = 10/7 = 617c;

A/C=5/11=20/11=1035c;

A/D=5/13=20/13=746c;

B/C=7/11=14/11=418c;

B/D=7/13=14/13=128c;

C/D=11/13=22/13=911c.

Hexany = 128c 418c 617c 746c 911c 1035c

These next lines show how the inversion of the hexany is derived. Notice that above, the first ratio is A/B. To get the inversion, simply reverse the terms: B/A.

Inversion

B/A=7/5=583c;

C/A=11/5=11/10=165c – etc.

Hexany Inversion = 165c 289c 454c 583c 782c 1072c

Finally, the 6 possible ratios of all combinations of the four chosen harmonics are calculated.

Combinations: AB/CD; AC/BD; AD/BC; BD/AC; BC/AD; CD/AB

As an example C*D/A*B = 11*13/5*7 = 143/35 = 143/140 = 37c

Combination Hexany: 37c 293c 328c 872c 906c 1163c

Refer to Hexany Diamond diagram in Figure 5 for all relationships possible within this scale.

4.2 The Complete Scale listed in Scala format.

0:	A/A	1/1	0.000000	unison
1:	CD/AB	143/140	36.705984	
2:	B/D	14/13	128.298245	2/3-tone
3:	C/A	11/10	165.004228	4/5-tone, Ptolemy's second
4:	D/C	13/11	289.209719	tridecimal minor third
5:	BC/AD	77/65	293.302473	
6:	AC/BD	110/91	328.278088	
7:	B/C	14/11	417.507964	undecimal diminished fourth or major third
8:	D/A	13/10	454.213948	tridecimal semi-diminished fourth
9:	B/A	7/5	582.512193	septimal or Huygens' tritone, BP fourth
10:	A/B	10/7	617.487807	Euler's tritone
11:	A/D	20/13	745.786052	tridecimal semi-augmented fifth
12:	C/B	11/7	782.492036	undecimal augmented fifth
13:	BD/AC	91/55	871.721912	
14:	AD/BC	130/77	906.697527	
15:	C/D	22/13	910.790281	tridecimal major sixth
16:	A/C	20/11	1034.995772	large minor seventh
17:	D/B	13/7	1071.701755	16/3-tone
18:	AB/CD	280/143	1163.294016	
19:	A/A	2/1	1200.000000	octave

4.3 How the Scale is used in this piece.

Here's how the instances of Orbit are tuned – (or as closely as possible that the fine tuning control of Orbit will allow) – remember, there are three instances of Orbit being used in each pass of this piece, and each instance of Orbit allows only 4 precisely tuned tones at a time, which means that each pass of the piece will have 3 tetrachords, for a total of 12 pitches (out of 19) being used in each pass. Octave placement is determined by if the ratio in the Hexany Diamond is, say 7/11 (lower octave) or 11/7 (normal octave) or an octave below or above, depending on the ratio:

Pass 1 Instance 1 BD/AC 871c; B/A 582c; B/D 128c; B/C 417c – chord 1:

Pass 1 Instance 2 AB/CD -36c; B/C -782c; D/C 289c; A/C -1365c – chord 2:

Pass 1 Instance 3 BC/AD 293c; B/A 582c; D/A 1654c; C/A 1365c

Pass 2 Instance 1 AD/BC -293c; A/C -1365c; A/D -1654c; A/B -582c

Pass 2 Instance 2 AC/BD -871c; CD 782c; D/B 1071c; A/B -582c

Pass 3 Instance 3 CD/AB 1236c; C/A 1365c; C/D -289c; C/B 782c

This makes a total of 6 tetrachords for the entire piece. Each pass uses 12 pitches, which when combined encompass 18pitches from the 19-tone scale. Only the 1/1 A/A is left out.

Again, two passes were made in real-time and mixed together. With the MusicWonk patch, changes were improvised in depth, individual instance rhythm and saw/sine voice alternation envelopes, using the patch shown in the upper half of Figure 2. As mentioned earlier, by 8 minutes in all depths of the alternating timbres were set to 0 so that the full cluster chord was heard. At 9 minutes, all depths on all channels were faded back up to 100 so that there would be a return to the polyrhythmic texture which started things off for the final minute of the piece. My normal compositional practice would usually involve setting up some kind of algorithmic process to control the details of the piece as they unfolded. With Orbit, and the given tuning, I felt that the patch itself embodied a kind of algorithmic process, and that all I needed to do for each pass was to improvise a selection of alternations between polyrhythmic textures (the irrational polyrhythms themselves produced by low frequency oscillators controlling the clocks on the Plogue sequencers), and full textured chords in order to create a structurally satisfying structure. The 10 minute piece which resulted from this is part of a much longer piece "Hexany Diamonds and Others" which was produced in 2019, using, among other resources, multi-timbral instruments referred to in this text (Infundibulum, Kepler Orchestra, Orbit, Eclipse) and a number of other Hexany Diamond scales among other tunings. The entire piece lasts 130 minutes and consists of 13 movements.

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A TRIALOGUE ACROSS THREE TIME ZONES

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Monash University

Laurie Spiegel
Composer,
unaffiliated

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University Of British Columbia

ABSTRACT

For the past many months three composers, Laurie Spiegel. Kenneth Newby and Susan Frykberg, from New York, Vancouver and Melbourne respectively, have been involved in an internet-based conversation on composition, composing systems, computer-music, spirituality and birds/animals. The conversation was initiated by Melbourne-based composer Susan Frykberg, who wished to discuss a number of issues relating to her PhD at Monash University on spirituality and electronic music. This paper identifies six important themes from the conversations: Reasons for composing; spirituality in music; notation; algorithms; coding and animals. While key themes from our conversation are summarized below, the give and take of the trialogue, which spanned months of an ongoing three-way conversation, is best represented in another form. Therefore a version of the conversation can be seen on Tumblr link. We believe it reveals something of the multi-faceted, evolving and relational nature of the creative musical mind.

1. PARTICIPANTS

Laurie Spiegel is well-known for her use of computers for composing, improvisation and the music software she has written for personal computers. She also does visual art in various media and has published widely on technology in the arts and its socioeconomic effects. She eschews spirituality per se, but is deeply interested in consciousness, cognition and mythology.

Kenneth Newby is a composer-performer, media artist, educator, interaction designer and audio producer. His creative practice explores the use of technology to enable the creation of music, media performances, installations and experiences rich in aural, visual and cultural nuances. His current work is focused on the continued evolution of his computer-assisted composition system, the Flicker Generative Orchestra.

Susan Frykberg is a sound artist and composer who has long incorporated technological, feminist, environmental and spiritual ideas through works for electroacoustics, acoustic instruments, intermedia, chant and improvisation. She has also created music software. She is an active member of several spiritual and religious groups including interfaith organizations and has created liturgies for some of these communities.

2. REASONS FOR COMPOSING

For Laurie, emotion and craft seem to be key. I "craft experiences... They can be experiences of love, wonder, beauty, exhilaration or sadness. The listener is key... Music involves every aspect of being alive, the physical, emotional, intellectual, rational and intuitive parts, and what Susan would call 'spiritual' too. Music by others has helped me many times in my life. I want to do that for others as well as myself. When I find that no music exists that touches, expresses, embodies something intense that I experience inside of myself, I want to create it, for that feeling or imagining not to remain isolated; to express, share, communicate. And I compose out of love of the process, the sense of flow and due to just plain fascination."

For Susan, sound art and composition is a kind of language for commenting on and exploring a wide range of ideas, from women's issues to religion. The language is continually evolving, is sometimes algorithmic and pays particular attention to sonic palettes that have their own kind of 'life.' It incorporates electroacoustic music, soundscape, signal processing, chant and technological innovation, to provide a terrain for exploration and comment on self and other. A specific example is her Audio Birth Project. Fascinated by the experience of giving birth to her son Esha, Susan investigated the birth processes of her sisters and mother. Edited interviews, extrapolated structures, soundscapes, granular synthesis and live instruments were then combined to create four new works.

Kenneth says: "My own practice is grounded in ... research and intuition (finding the sweet spots in that combination).....[and] exploring generative musical poetics. The advantage of working in a generative context is that it enables the composer, through the formulation of a personal theory of music, to effectively explore the infinite design-space of music, to zero in on the richer veins of creative potential. In this sense the

software environment is not based on a concept of artificial intelligence (AI), but rather an amplification of intelligence (IA), that leverages the embodied skills of the composer. The resulting balance of research and intuition produces a novel way of knowing oneself as a composer, performer, and listener."

Crafting listening experiences for others; exploring ideas through developing 'sonic languages'; research, intuition and technological innovation; music for self-knowledge; personal theories of music; sharing and communication of intense inner experience; the amplification of musical intelligence through technology; creating music to help others and generative musical poetics are therefore key concepts. Probably all of them play a part for each of us but with different emphases, depending on the particular compositional project.

3. SPIRITUALITY IN MUSIC

The significance of spirituality is different for each of us, yet we all acknowledge its role in music to a significant degree. Laurie eschews the word for her own practice and prefers to speak of psychology, emotion and myth. Kenneth articulates an evolving form of personal spirituality that integrates a number of concepts from different traditions. Susan is a practicing Catholic, leads Christian meditation and chanting groups and is involved in interfaith dialogue with traditional religions such as Islam and Judaism. Kenneth says "Music as an art of sculpting time for our experience..... [would] seem to be a medium most suited to articulating the spiritual...I've been thinking about the way music allows us to traverse the seemingly infinite space of consciousness. Music is not only resonant with embodied or emotional states, but provokes strong resonance with the flow of consciousness at deeper levels, accessing the subtlety and nuance of the forms of reality we render from the 'blooming, buzzing confusion' of direct experience."

Laurie comments on the distinction between cultures who use music to pursue the ecstatic in spirituality, versus spirituality as quietude, with Sufi music and Gregorian chant as examples respectively. She also notes the role of spirituality in the New York downtown scene in the 70s, saying, "In experimental music here in downtown NY, a lot of the drone and minimalist music is conceptualized as relating to Zen (for example Pauline Oliveros), Tibetan Buddhism (Phil Glass), or the Vedic traditions (LaMonte Young). Music can alter how we experience whatever we're going through, as does meditation and religious belief systems."

Susan is interested in what Jeremy Begbie calls the Great Tradition (Begbi 2007). He argues that music/sound is an analogue for a God-created/infused cosmos, which includes the universe, nature and the human's ethical life. It is also mathematical and geometrical. The Great Tradition begins with Pythagoras and continues through Plato, Augustine and Kepler, via Boethius, who distinguishes between theoretical musical structures describing cosmos, world and seasons, (musica mundana), human nature, (musica humana) and actual music played, (musica instrumentalis).

4. NOTATION

Kenneth comments on how notation tells the performer what to play, but not how to play. He says: "It's good as a mnemonic device - it's a tradition, grid-like, quantized in nature." Kenneth's experience in playing all sorts of notated, un-notated, composed, improvised, and intercultural music has influenced his thinking about algorithmic music: "I've set myself the challenge of creating an orchestra of virtual players and given them the task of expressively interpreting the musical structurings. This has led to the creation of a theory of performance based on a notion of musical information. I includes the metric position of events in a temporal hierarchy, features that can be extracted from a melodic flow, and global states based on higher-level dynamic features such as speed, density, connectedness, loudness, etc. These features are mapped to playing styles that can produce a wide variety of interpretations of a given structure."

Laurie comments on the role of notation in a number of aspects of her musical composition practice. "I do sometimes write musical notations, traditional or graphic, to organize my own thoughts and sounds during the process of composing a work, whether I then fully realize it electronically or give it to other people to play on an instrument. This is notation functioning not as instructions but as an organizational tool for my own musical thinking. Notation is a language in which we can work out structures and go from vague idea to detailed complete thought. I also find pencil and staff paper the freest, most spontaneous way to work with sounds other than live improvisation. It is easier to break out of pattern with a pencil than any computer software I know, and quicker to jot an idea down. It is perhaps the only truly parallelistic, multidimensional human language, accommodating many kinds of structures."

For Susan, the role of notation is constantly evolving and depends on the current project. An electroacoustic piece may require diagrams indicating spectral and temporal material as well as mixing and diffusing instructions. An acoustic piece may use traditional notation and an aleatoric piece may combine text, images, technical information, musical notation and graphics. Two of her recent acoustic works have simply used traditional notation, via the program Sibelius, but most others use a combination of methods. Free-hand drawing of shapes provide structural guidance for early compositional explorations. Rhythmic patterns from Greek and Latin poetic traditions are often used as a base for a variety of accompaniments. Images, sometimes actual art works, are used as guidance for structured improvisation. Fragments of traditional chant, sometimes in its original notation, (neums or pre-neumic notations), are present in some works. Finally, because some of her pieces have a theatrical component, (e.g.

Suffering, premiered at the 2011 ACMC conference in Auckland, New Zealand), use theatrical, technical, textural and lighting instructions as part of the notation.

5. ALGORITHMIC MUSIC

Laurie's works using a variety of her algorithms (Spiegel n.d. A) at Bell Telephone Labs in the 1970s, can be heard on her album The *Expanding Universe* (Spiegel n.d. B). Her program *Music Mouse – An Intelligent Instrument* (Spiegel n.d. C) is well known, having been widely available on several personal computer platforms. She says "I think of algorithmic logic as being like a ladder to let us reach further. Logic lets us take care of decisions we can automate in order to be free to focus on the aspects of music that can't be automated, which we reserve to our intuitive sense of what feels right. Mathematical and logical structures are often beautiful in themselves, but music has to do, at least for me, with the expression and communication, the sharing with others, the embodiment outside of ourselves of both imaginative and emotional subjective experience. We are otherwise alone in our inner experiences, trapped within our minds, experiencing what we do in isolation. Algorithmic logic is an extremely useful tool for that."

Kenneth Newby is a multi-instrumentalist, playing piano, woodwinds, and a variety of gamelan instruments. Yet his interest in algorithmic music makes the computer his primary instrument and his Flicker Generative Orchestra is based on a personal theory of musical structure, its composition and performance. "By a process of introspection—answering the questions around 'how I do it, how I feel it', I seek methods and techniques that can be encoded in a computational form and integrated into an interacting set of procedures for the generation and performance of music. This introspective approach is augmented by a comprehensive study of the literature in theory, cognition, and psychology of music as it is perceived and performed, as well as research into extant approaches to algorithmic composition. I think of this as a grounded personal theory of music. The compositional system is a kind of model of musical mind, or a mirror held up to one's own understanding and abilities of how the form of music works. As Otto Laske (Laske n.d.), one of the pioneers in the field of cognitive musicology characterized it, we engage in a novel form of epistemology or knowing of the musical self when making such models."

While Susan has written programs to compose, her main focus is via sonic categories which somehow have a degree of 'their own life'. Granular synthesis, soundscapes, recorded speech and apps with an AI component, such as SECTOR and Refractions all have, to a greater or lesser degree, specific unique qualities that require detailed attention through repeated listening. They can only be worked with after this process and because of this, the business of composition is probably better thought of as a kind of co–creative endeavour with an existing form of sonic semi-life.

6. ON CODING

For algorithmic composers, coding is an integral part of the practice. Kenneth has described coding as his cognitive yoga – a delightful term that reminds us that the intellect and the spiritual are well-connected. Kenneth says: "Coding is my practice. Can't avoid it! Then again, code can be looked at as a radical development in notation/writing... a notation that has agency, is active... Code that specifies a deterministic musical process, might be read in the same way common music notation is, the reader is able to hear the music represented by the symbols. An interesting difference, of course, is the fact that.. common music [notation] indicates a thing already made, whereas the code specifies its making. Things get really interesting when the code becomes complex enough in its makings that the outcome is not predictable from the processes... and we get emergence—the computational sublime."

Laurie comments that "it's not the code itself that is active. It's a set of instructions functionally comparable to a musical score or a recipe. They all require external agency to produce realized results. In essence, an algorithm is a general statement describing a process and producing results. It is a shorthand for many specifics, an automation of process. We can concisely specify many details by generative algorithms, and to the extent that we can figure out our own musical decision-making processes as composers, we can automate what we do ourselves in our minds almost by musical reflex...We are free to feel more, go deeper, concentrate more intently on what is not automatic or a reflex in our minds, and to see the whole instead of being bogging down in detail. Often though, we find something unexpected that is wonderful... It's a form of introspection to try to capture in logic what might make good music...and to generate what sounds right to our ears. It's an exciting learning experience as well as a way to increase our musical capabilities."

6. ON ANIMALS

Each of us have a particular affinity to animals – Laurie to 'underdog species' especially pigeons, (Feisst n.d.) as well as a lifelong succession of pets; Kenneth to his 'wild companions' and Susan to the large number of pets she takes care of in the greater Melbourne area in her role as professional house-sitter.

Laurie says: "Animals live much more entirely in the moment than we do. And they don't let language and all the abstractions which complicates our awareness, interfere with their being in the moment here and now. That's not to say that they don't have memories, fears, wishes, the awareness of futures possible and past. But they are much more in the moment I think, and they can concentrate on what or who is right in front of them more purely and intensely than us distracted beings...So we might think of animals as natural meditators."

Kenneth speaks particularly fondly about wild animals – frogs, ravens, hummingbirds, a snake, and adds: "when we attune ourselves to that 'in the moment-

ness' with them we're gifted with some of their way of being/becoming in the world. It always feels like a great honour to have the trust of a free (non-captive) animal. In these interactions we get the opportunity to share the experience of being more than the sum of the bodily functions encapsulated by our skin, as well as grasping at different ways of being in the world. I try to know myself better through my interactions with them."

Susan also comments on the spiritual relationships between herself and the animals she takes care of as a professional house-sitter. They provide her with companionship and an 'in the momentness' close to the quality of contemplation. Many of the animals are regulars and there is a sense, it seems from both sides, of spending time again with 'old friends'. For new animals, there is always a time of adjustment: "We take a while to co-habit on a psychic level."

7. IN SUMMARY

This paper briefly identifies six themes from our three-way conversation: reasons for composition, spirituality and music, notation, algorithms, coding and animals. Key themes from our conversation are summarized here, but more of the give and take of the ongoing trialogue the can be seen on the Tumblr link. We believe that the conversational form is of particular interest to composers because it indicates the relationality and multi-faceted, evolving and relational qualities of the creative, contemporary musical mind.

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NES-SPECTRALE: A SUITE OF MAX TOOLS FOR PROCESSING IN THE FREQUENCY DOMAIN

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ABSTRACT

This project's aim was to explore the notion of "timbre processing" using Jitter matrices as the store and processing mechanism. The NES-Spectrale suite of Max/Jitter patchers is a structured set of tools for processing sounds in the frequency domain, and inverse transforming the results into the time domain, in the form of audio signals. This collection of software tools extends the work of Jean-François Charles, providing an efficient and novel approach to FFT-based processing.

1. INTRODUCTION

NES-Spectrale was created for people who want to process portions of sounds in the frequency domain. The workflow is as follows: Use a sound file or live audio as a starting point; Record a portion of it in the frequency domain (FFT); Process it in some way, in the frequency domain; Render the result as audio, in the time domain; Record the result.

Inspired by the work of Zack Settel and Cort Lippe (Settel and Lippe 1994), Jean-François Charles (Charles 2008), and the GRM Spectral Transform and Evolution suites of audio processors, the project adapted the patches of Jean-François Charles into a set of FFT processing tools using Ableton/Cycling 74's Max environment, with Jitter matrices storing and processing the FFT. This project's aim was to explore the notion of "timbre processing" using Jitter matrices as the store and processing mechanism.

The NES-Spectrale suite is as follows:

- Interpolate-periodic, freezes two slices of sound and interpolates between their frequency content over the set interpolation period;
- Multi-FX-05, lets you select one of five Jitter effects to apply to the FFT matrix;
- Playtwo, has two independent play heads that can be adjusted to play across different frequency bands at different rates;
- Playfour, the same, but with four play heads;
- Transform-Mx, uses the jit.mxform2d object, which performs a 2-dimensional matrix transform on an input matrix. It can be used to perform scaling, rotation, skewing, and perspective operations.

2. BACKGROUND RESEARCH

2.1. David Hirst

In 1985, I submitted a Masters thesis entitled *Digital Sound Analysis and Synthesis Using the Short-time Fourier Transform* (Hirst 1985). As the title suggests, this thesis explores the use of the short-time Fourier transform (STFT) techniques in digital sound analysis and synthesis, but with particular reference to musical applications. It built upon the work of Michael R. Portnoff whose 1980 doctoral dissertation was published in the form of two papers in the same IEEE journal (Portnoff 1981a, 1981b).

The first application of my Masters work to musical systems was in the analysis of acoustic phenomena. A FORTRAN program was written to analyse sound using the STFT, make some data reduction, then display the analysis data on a terminal to allow for human interaction in the evaluation of important sound information. This was quite a laborious process since the sound(s) had to be digitally recorded on a PDP 11/10 mini computer tape within the Music Department. The digital tape was then transported to La Trobe University's computer centre, where an overnight batch process would run on a Vax 11/780 mainframe computer to mount the tape, read the sounds file(s), perform the analysis, and store the analysis data on disk. From there it could be read and displayed on a specific type of computer terminal, or visual display unit back in the Music Department.

A method of additive synthesis was devised, for the software synthesis program MUSIC4BF, that used the time-varying amplitude and frequency parameters of important partials. As a test of the analysis-synthesis system, a number of Marimba tones were resynthesized, employing differing types of mallets, and the audible results evaluated.

The third application of the analysis system was in the direct coding and modification of the short-time Fourier transform and subsequent inverse transform resynthesis using the Fast Fourier Transform. Different signal modifications tested included fixed and time-varying filtering, spectral bin shifting, pitch transposition independent of time, time-scale expansion independent of frequency, and signal mixing through transform addition. In this latter application a method of phase compensation was proposed that used difference equations in the calculation of phase change, interpolation techniques and

the overlap-add synthesis procedure with a specified amount of overlap. At the time, none of this work was possible in real time.

The final test of any analysis-synthesis system is in its use in a musical context. With this in mind, the composition *Betameta* was created to provide an artistic end to a convoluted technical path. *Betameta* was stochastically composed using a changing beta function to organize the attack points, durations, melodic intervals and stereo placement of the sonorous material. The organization of timbre used both the Marimba simulation instrument and the extension of the instrument derived from the initial experiments. *Betameta* was selected for performance at the International Computer Music Conference (ICMC) at the Eastman School of Music, New York in 1983.

2.2. Mark Dolson

At the same 1983 ICMC at Eastman, Mark Dolson presented a paper on the 'Musical Applications of the Phase Vocoder'. Also inspired by Portnoff, Dolson's work was published in the form of a tutorial article in the Computer Music Journal (Dolson 1986). It went on to become the definitive reference article for the study of the "phase vocoder" (as it was beginning to be called then).

In the 1986 article, Dolson provided two interpretations of the phase vocoder. Firstly as a filterbank interpretation, then as a Fourier transform interpretation, and showed how they are equivalent. He also discussed phase unwrapping, the trade off between time resolution and frequency resolution, and he provided some examples of applications such as analysis, time scaling and pitch transposition. In his conclusion, he briefly mentioned further processing possibilities:

> In addition to simple time scaling and pitch transposition, it is also possible to perform time-varying time scaling and pitch transposition, time-varying filtering (e.g., cross synthesis), and nonlinear filtering (e.g., noise reduction), all with very high fidelity. The phase vocoder analysis capabilities alone can be extremely useful in applications ranging from psychoacoustics to composition … (Dolson 1986: 24-25)

2.3. Zack Settel and Corte Lippe

By 1994, Zack Settel and Corte Lippe, working at IRCAM in Paris, were able to take advantage of specialized real-time signal processing equipment, the IRCAM Signal Processing Workstation (ISPW), to explore real-time musical applications which "made use of FFT/IFFT-based resynthesis for timbral transformation in a compositional context" (Settel and Lippe 1994: 171).

The FTS-Max programming environment developed by Miller Puckette at IRCAM (Puckette 1991) enabled Settel and Lippe to develop algorithms and basic operations to process the FFT of an audio signal. Using the overlap-add technique, their basic order of operations was thus:

1. Window the input signals
2. Transform the input signals into the spectral domain using the FFT
3. Perform operations on the resulting spectra
4. Resynthesis of the modified spectra using the IFFT
5. Window the output signal

(Settel and Lippe 1994: 172)

The processes they explored were: high-resolution filtering; low dimensional control of complex spectral envelopes; cross synthesis (multiplying two spectra); mapping qualities of one signal onto another; frequency dependent spatialization; and a frequency-dependent noise gate.

2.4. Jean-François Charles

Jean-François Charles' 'Tutorial on Spectral Sound Processing Using Max/MSP and Jitter' (Charles 2008) explores graphical spectral analysis and synthesis in real-time using the Jitter matrix processing capabilities of the Max visual programming environment.

Charles takes an FFT of a signal and stores the FFT data in a two "plane" matrix, one plane for amplitude and one plane for phase (Charles 2008: 90). Each plane consists of a 2D grid where the grid height is the number of frequency bins (half the FFT size) and the grid length is the analysis windows (or total frames). Once the FFT of a sound is stored in this way, operations can be performed on the FFT matrices using standard Jitter transformations.

The simplest type of sound modification is recording and playback, where the playback speed can be varied. Charles points out that when playing back at slower speeds, there can be an observably audible "frame effect". To combat this effect Charles implements two methods to interpolate spectra between two recorded FFT frames. The first method makes use of the jit.xfade object to cross-fade between two spectral frames. The second method is a controlled stochastic spectral synthesis, with a probability of picking up values from the next frame specified as a fractional value given by the user. This choice is made for each bin. This stochastic method has the advantage in that it can be extended over a number of frames (e.g. 5 frames) to create a blurring effect.

Charles then goes on to outline graphically based transformations of the FFT representation in the form of direct transforms, use of masks, interactions between sounds, and mosaicing. He also provides examples of real-time freezing, automatic cross-fading, and melody-to-harmony creation using a modified freeze tool. The topics of transient detection and signal segmentation are also covered.

3. NES-SPECTRALE DETAILS

3.1. NES-Spectrale overview

The NES-Spectrale suite extends the work of Jean-François Charles by implementing specific examples of

FFT processing using the special capabilities of Jitter matrices and their operators.

The normal way of utilizing NES-Spectrale is as follows: Record a portion of sound as a series of successive spectra in the frequency domain (FFT); Process it in some way - in the frequency domain; Render the result as audio, in the time domain; Record the result.

The NES-Spectrale suite is summarised in Table 1.

NES-Playtwo	has two independent play heads that can be adjusted to play across different frequency bands at different rates
NES-Playfour	has four independent play heads that can be adjusted to play across different frequency bands at different rates
NES-Interpolate-periodic	freezes two slices of sound and interpolates between their frequency content over the set interpolation period
NES-Interpolate-periodic-02-ST	This is a stereo version of NES-Interpolate
NES-Distort-Del-Fbk	Combines non-linear distortion, multiplication and addition to the FFT index, and adds delay and feedback, frequency bin by bin
NES-Multi-FX-05	lets you select one of five Jitter effects to apply to the FFT matrix
NES-Transform-Mx	uses the jit.mxform2d object, which performs a 2-dimensional matrix transform on an input matrix. It can be used to perform scaling, rotation, skewing, and perspective operations

Table 1. NES-Spectrale suite of transformations.

4. DESCRIPTION OF NES-SPECTRALE PROCESSORS

NES-Playtwo

NES-Playtwo has two independent play heads. They can be adjusted to play across different frequency bands using the Lo_Freq and High_Freq sliders.

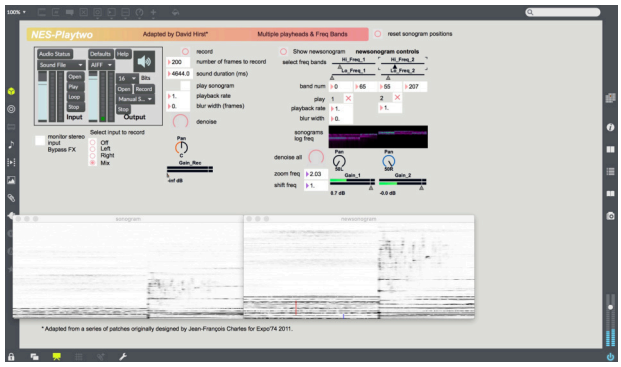

Figure 1. NES-Playtwo[1]

Each has an independent playback rate, pan, and gain control. Each has a mini log frequency sonogram display. The common controls are: blur width and denoise. The "zoom freq" and "shift freq" controls can be used to get finer control by zooming and shifting the new sonogram display. The latter two controls are for visual purposes only and do not actually effect the frequencies themselves.

NES-Playfour

NES-Playfour has four independent play heads. They can be adjusted to play across different frequency bands using the Lo_Freq and High_Freq sliders.

This is merely a four head version of NES-Playtwo with the same kind of controls.

With each of these processors, playing direction can be forward or reverse.

Figure 2. NES-Playfour

NES-Interpolate-periodic

NES-Interpolate-periodic (Fig. 3) freezes two slices of sound and interpolates between their frequency content over the set interpolation period. By default, this is 3 seconds, but the value can be varied from very short to very long. As long as the soundfile is playing, this periodic snapshot of the spectrum of the sound will continue, with interpolation happening between the latest two snapshots. Turn "Interpolation" ON and power spectrum 1 will appear and then power spectrum 2 will appear after 3 seconds. As Figure 3 shows, the interpolated spectrum

[1] Note that the screen shots in this article depict the general layout only. For detailed views, download the NES-Spectrale suite from https://davidhirst.me/software/ and run the patchers using Max 8 from https://cycling74.com

will appear below the other two. Turn Bypass FX off, and you will hear a progression from one timbre to the other. The wet/dry control determines how much of the original and the effect you can hear.

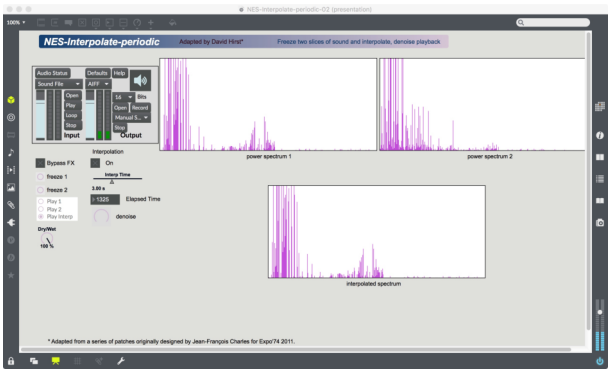

Figure 3. NES-Interpolate-periodic.

"Elapsed Time" shows the current time since the last spectral snapshot. When it reaches the interpolation time, a new spectral snapshot happens, and a new interpolation begins between the latest two spectra.

"Denoise" allows you to remove frequency bands below the set amplitude threshold. "Freeze 1" and "Freeze 2" allow you to manually jump to a new freeze point in the looping sound file. "Play 1", "Play 2", and "Play Inter" permit you to play either snapshot alone, or the interpolation between the two. It is normally set to "Play Interp".

NES-Distort-Del-Fbk

NES-Distort-Del-Fbk combines non-linear distortion, multiplication and addition to the FFT index, and adds delay and feedback, frequency bin by bin. Figure 4 shows that you can draw in the function tables to change the feedback and delay on a per FFT bin basis. This is similar to the transfer function used in waveshaping synthesis, however the distortion is in the frequency domain rather than the time domain.

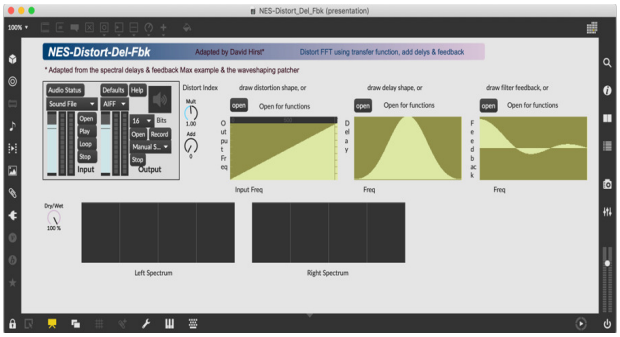

Figure 4. NES-Distort-Del-Fbk effect from the NES-Spectrale suite.

Drawing in the 'distortion shape' function will create more distortion the further the plot moves away from a 45 degree type line, often yielding unpredictable results. Experiment, especially in the very low values, to produce unusual, distorted sounds. You can always get back to the original line by clicking 'Open' to open a pop-up menu of functions and choosing the 'Default – no distortion' option.

NES-Multi-FX-05

NES-Multi-FX-05 lets you select one of five Jitter effects to apply to the FFT matrix. There is a TAB to select the effect, and each has its own interface, with parameters you can change.

Before getting into the details of the effects and how they are controlled, first a comment regarding the novelty of these processes. The first three patches, already described above, store the FFT in a Jitter matrix form, but are really using the matrix as an efficient storage mechanism to perform fairly traditional playback of audio when converted back from frequency domain form. With NES-Multi-FX-05, we are really using Jitter transforms that were designed for visual transformation to change the stored FFTs in a way that may not have any acoustic basis whatsoever, but which can nonetheless yield interesting and creative musical results. It is really five patches in one, and with any one of the five different transforms, experimentation is the key. The results will depend on that experimentation and be highly dependent on the nature of the sound source. With experimentation in mind, the common elements of the five effects will be summarized, then there will be a section on each effect.

There is a "limiter" built into the patch. Its controls can be accessed by pressing the "Open" button on the left hand side below the "monitor stereo input" button. Its level can be adjusted here too. Processing the FFT can lead to loud sounds. The limiter is there to account for this, but it is always wise to start with all the levels in the chain turned down, then slowly bring the levels up to a comfortable listening volume – starting at the input source and working towards the output destination.

Each of the effects will now be summarized in turn. Note that the descriptions are from the Max Jitter documentation, so they apply to the visual effect on the FFT window. The sonic effect can only be predicted by trying various settings out.

Plur

Peace Love Unity Rave

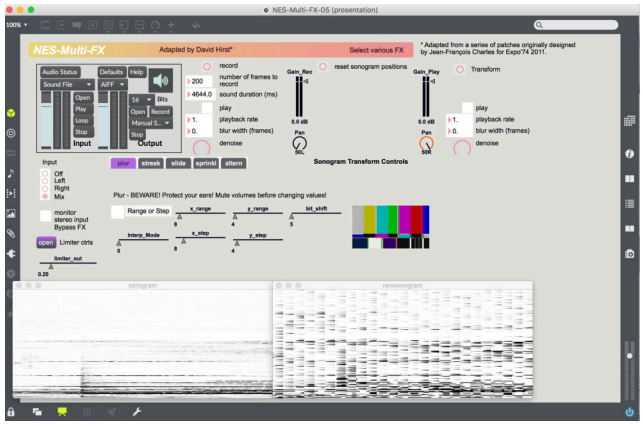

Figure 5. NES-Multi-FX-05: Plur

Use the jit.plur object to perform linear interpolation on incoming matrix frames. This object resamples an image and then interpolates back to the original size in the following manner.

The resampling process uses two different attributes along each axis of the matrix frame. The 'step' attributes determine how the frame is divided at output. For instance, with x_step set to 5, there will be a resampled rectangle every 5 cells along the horizontal axis. The 'range' attributes determine how that resampled rectangle is interpolated. If x_range is less than or greater than x_step, different corner points are used for the interpolation calculation, than are used in the resampling. This tool has been found to be useful for creating rhythmic effects: either rapid or slow.

Streak

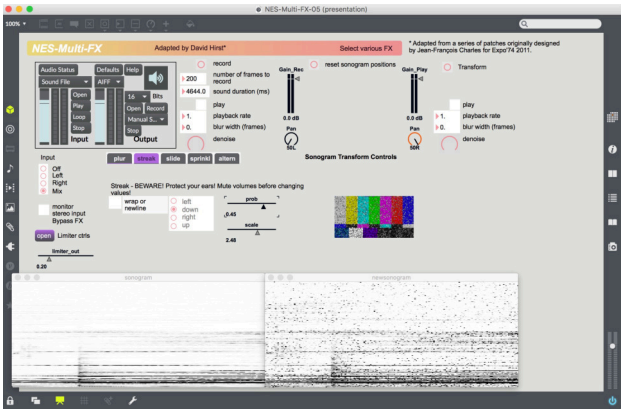

Figure 6. NES-Multi-FX-05: Streak

The jit.streak object uses a specified probability to determine the chance that a given matrix cell's value will be extended to subsequent cells (with an optional scaling factor). The result is a pointillistic variation of the source sound.

Slide

The jit.slide object performs cellwise temporal envelope following.

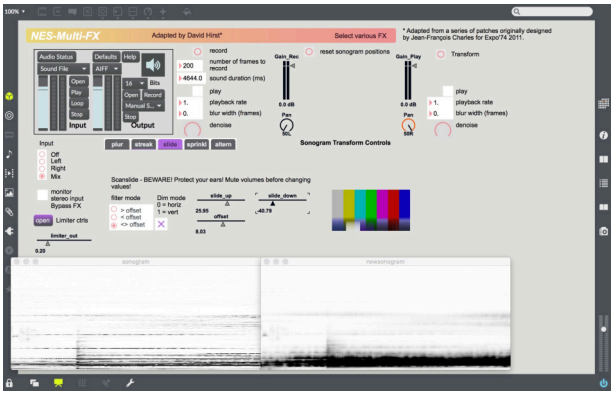

Figure 7. NES-Multi-FX-05: Slide

The slide down factor (default = 1) refers not to spatial change along the y axis, but rather with respect to amplitude (e.g. brightness of color channel for image data).

The slide up factor (default = 1) refers not to spatial change along the y axis, but rather with respect to amplitude (e.g. brightness of color channel for image data). The net audio effect is one of blurring the sound.

Sprinkl

jit.sprinkle probabilistically determines whether a matrix cell will be displaced by a random amount along the horizontal or vertical axes to produce a "cloud" of data surrounding the original cell values.

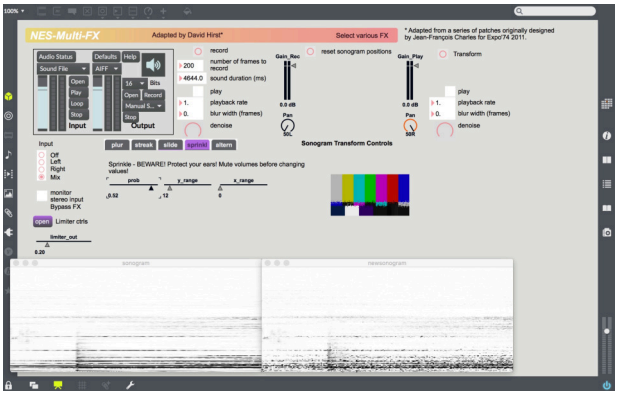

Figure 8. NES-Multi-FX-05: Sprinkl

The probability that any given cell will be displaced is determined by the 'prob' variable (default = 0). The displacement range along the horizontal axis uses 'x_range' (default = 0), and the displacement range along the vertical axis uses y_range (default = 0). The audio result is pointillistic, like the streak effect, but if the playback is slowed down a lot, new "melodies" can be generated through the frequency changes.

Altern

Overlays a screen onto incoming matrices. The original matrix values are revealed through "gaps" in the screen.

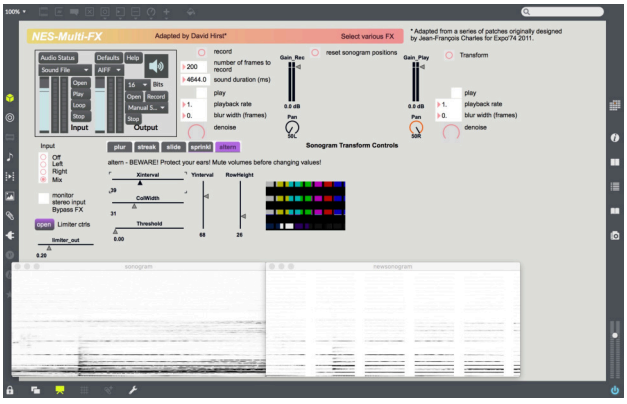

Figure 9. NES-Multi-FX-05: Altern

The width of the vertical band "gaps" in the screen is specified by colwidth (default = 1). The height of the

horizontal band "gaps" in the screen is determined by rowheight (default = 1), and the luminance threshold as an average of plane values is varied using thresh (default = 0). Input matrix values above this threshold are displayed as a grid of rectangular "gaps" between the overlaid horizontal and vertical screen stripes. Values below the threshold are displayed. (Usually leave this on '0' to get an image.)

'xinterval' specifies the spacing of "gaps" in the screen along the horizontal axis (default = 1), and 'yinterval' the spacing of "gaps" in the screen along the vertical axis. (default = 1).

This 'screen' or 'grid' type of effect is reminiscent of the grids used by Xenakis, but with resect to time and frequency only. Altern can be used to create rhythmic effects or changes in timbre, or both.

NES-Transform-Mx

NES-Transform-Mx uses the jit.mxform2d object, which performs a 2-dimensional matrix transform on an input matrix. It can be used to perform scaling, rotation, skewing, and perspective operations. Jit.mxform2d is a complicated transformational object, and I have tried to label the interface sliders in plain language to describe the function. Note that their values have been limited to a useable range. The best way to learn the functions is to try and vary each one on its own by adjusting it a small amount. The colour bar visual will guide you as to what each parameter is doing – skewing, scaling, or rotating. The observed effect is totally dependent on the very important "Boundmode" parameter, so its values and meanings are reproduced in the Readme file for the suite.

This tool is especially adept at glissandi-type effects.

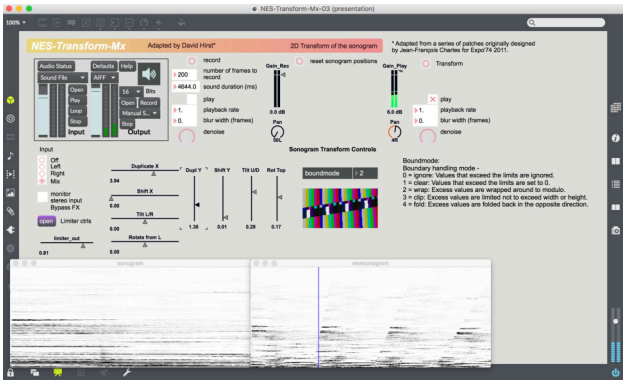

Figure 10. NES-Transform-Mx

5. CONCLUSION

The NES-Spectrale suite is a collection of FFT-based signal processors. NES-Spectrale utilizes an efficient way of storing an FFT in a Max/Jitter matrix, and it also facilitates fast processing of these matrices using Jitter's built in matrix manipulation functions. In addition to speed and efficiency, using Jitter matrices affords novel ways of manipulating sound in the frequency domain. Especially useful are the NES-Interpolate-Periodic; NES-Playfour; NES-Transform-Mx; and variable speed playback processing tools. With extended practice, the user can learn some very inventive and creative applications for NES-Spectrale.

As a recent extension to the work, several NES-Spectrale transformations have been written as plugin devices for Ableton Live 10: NES-Interpolate.amxd and NES-SpectralDelayDistort.amxd

These have been carefully programmed to allow for multiple instances in Ableton Live.

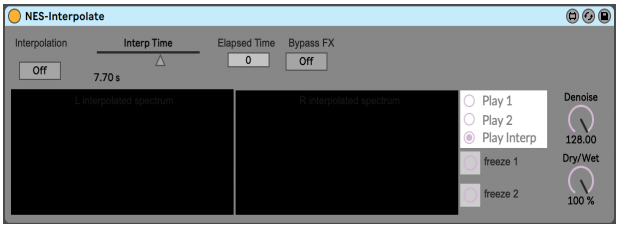

Figure 11. NES-Interpolate.amxd Max for Live device.

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SCHAEFFER, GRM AND THEIR INFLUENCE ON NES-TOOLS FOR MAX

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ABSTRACT

NES-Tools is a suite of audio signal processors emulating the GRM-Tools, but in the Max environment. This article provides the historical context for the creation of GRM-Tools, reaching back to the concepts developed by GRM's founder Pierre Schaeffer, providing a summary of technological developments at GRM, then describing the details of each of the NES-Tools. The adaptability of using the Max environment is demonstrated, and recent translations to Max for Live are noted.

1. INTRODUCTION

1.1. Aims

NES-Tools was inspired by the GRM-Tools suite of audio signal processors, created by the Groupe de Recherches Musicales (GRM) in Paris. The main aim for this project was to implement, within the Max[1] environment, the kind of audio signal processing tools found within GRM-Tools.

1.2. Background

In order to understand the unique collection that is GRM-Tools, it is helpful to examine the history behind this research group, and how the concepts that their researchers and composers developed were shaped by the technologies that underwent a period of rapid change, immediately after World War II.

The Groupe de Recherches Musicales (GRM) was set up by Pierre Schaeffer and the French Radio and Television service (RTF) in 1958 (Gayou 2007). Its predecessor was the Groupe de Recherche de Musique Concrète (GRMC, 1951–58). First we will examine the years before the formation of GRM, and the concepts Schaeffer developed as the years progressed (Palombini 1993; Gayou 2007). Then we will trace the origins and evolution of technologies used at GRM as articulated by Daniel Teruggi (Teruggi 2007).

2. SCHAEFFER AND THE PATH TO GRM

2.1. Before GRM

To understand both setup and the concepts espoused by GRM, we need to examine its gestation and the years leading up to its formation.

Schaeffer began experiments with radiophonic sound at the French Radio and Television service (RTF) dating back to 1942 (Gayou 2007). Beginning with the Studio d'Essai (1942–46), then the Club d'Essai (1946–60) and the Groupe de Recherche de Musique Concrète (GRMC, 1951–58), a unique approach to the composition of music using recorded sound was being developed.

2.2. Schaeffer Before 1942

Schaeffer was born in Nancy in 1910. He studied cello and went on to study engineering, specialising in telecommunications at the Ecole Polytechnique. He subsequently began his career as an engineer with the Radio Diffusion Française in 1936. In 1941 Schaeffer met George Gurdjieff, an Armenian guru who had travelled extensively but who had settled in Paris in 1922. Schaeffer was somewhat influenced by the teachings of Gurdjieff and Évelyne Gayou suggests that the notion of detachment from oneself and an opening up to the perception of other beings may have influenced Schaeffer's ideas about 'reduced listening', that is detaching sounds from their everyday meanings. (Gayou 2007, 204)

Working in groups was also a feature of Gurdjieff's teachings.

2.3. From 1942 (Beaune) to 1958 (GRM)

In the midst of World War II, and in German occupied France, Schaeffer collaborated with theatre director Jaques Copeau to organise training for practitioners of the emerging radiophonic arts: the Beaune training session. The trainees were chosen "for their pluri-disciplinary aptitude. They had to be actors, singers, musicians and technicians, all at the same time" (Gayou 2007, 205). The Beaune training session was "a model for Schaeffer, a successful symbiosis between art and craft, between research and creativity." (Gayou 2007, 205).

The Studio d'Essai (Trial Studio), was established in Paris on 12 November 1942. The Studio d'Essai "had to be both a laboratory of radiophonic art and a vocational training centre. Pierre Schaeffer at this time was working as the chief engineer at the radio, in charge of staff training." (Gayou 2007, 205). Not only did Schaeffer compose a radiophonic opera at this time, he also trained his team for secret activities in the Resistance, including the organisation of the radio broadcast calling for the liberation of Paris in August 1944. In quick succession,

[1] https://cycling74.com

after the liberation in 1945, he was made Director General of Radio, then fell out of favour and returned to Studio d'Essai, then was sent on a study tour of the USA and Canada to study radio there.

In 1946 the Club d'Essai followed on from the Studio d'Essai and was directed by poet Jean Tardieu. It was the start of an avant-garde period as the whole art world was more intent on exploring abstraction in the period after the war. Schaeffer was variously involved with the Centre d'Études Radiophonique and the Ministry of Foreign Affairs. In between foreign trips, he would return to the Club d'Essai to continue his experiments and develop his conceptual thinking. The period of research in the late 1940s by Schaeffer and his colleagues marked "the passage from realistic sound effects adapted to radiophonic theatre to a musical abstraction" (Gayou 2007, 205).

Schaeffer experimented with sound effects at the French Radio facility and this research into noise resulted in six "noise studies" (Palombini 1993, 14). The relationship between the abstract and the concrete and the process by which realisation of music is carried out were also issues explored by Schaeffer.

The very first appearance of the term 'musique concrète'[2] was at the presentation of Pierre Schaeffer's 'Concert de bruits' on Sunday 20 June 1948, at the Club d'Essai in Paris. As quoted by Gayou, Pierre Schaeffer made the notable declaration:

> To reach music, one can take an inverse path, which is to set out from sound data instead of notation, and from a former composition instead of a traditional execution. If the term did not seem so pretentious, we would call these attempts 'attempts at Musique Concrète', in order to better define their general character and because it is not so much a question of noise but of a method of musical composition. (Gayou 2007, 203)

Also, there was mounting interest created by the concert de bruits and the broadcast of a number of the noise studies by French Radio on Tuesday 5th October, 1948. This interest eventually led to "the publication of the article *Introduction a la musique concrète* (Schaeffer 1950), in which he felt reassured enough to replace the phrase 'research into noises' by the more ambitious 'musique concrète'." (Palombini 1993, 16)

Schaeffer's next work, in 1949, was the *Suite no. 14* (Suite for 14 Instruments). With the help of orchestrator Jean-Michel Damasse, Schaeffer produced a score for 14 orchestral instruments, which was then recorded. The recording was then "decomposed, shortened, magnified, dissected, inverted, exploded, pulverized" (Schaeffer 1952, 39). The theory being that if noises could provide material for musical construction, then less "arid" material should produce better results. However, what emerged was full of contradictions, and Schaeffer concluded that musique concrète produced powerful techniques, but that it lacked a theoretical grounding.

In 1949, Schaeffer also recruited young percussionist Pierre Henry to assist by performing on various sound objects in recording sessions. Their collaboration resulted in the *Symphonie pour un homme seul* (Symphony for a man alone) in 1949-1950. It was performed at the Salle de l'Empire in Paris on 6 July 1951.

In 1951, Schaeffer also lectured at the Darmstadt festival, where the Symphonie was enthusiastically received. His ideas were likewise warmly welcomed by German technicians.

Within the structure of the French national radio, Schaeffer formed the Groupe de Researches de Musique Concrète (GRMC) in 1951. GRMC was organised according to Gurdjieff's principles and experienced individuals trained the new composers. It attracted curious musicians and some of the "great names of the day followed one another: Andre Hodeir, Pierre Boulez, Olivier Messiaen, Michel Philippot, Monique Rollin, Karlheinz Stockhausen, Jean Barraque´, Darius Milhaud, Edgar Varèse, Henri Sauguet and Roman Haubenstock-Ramati." (Gayou 2007, 206)

The First International Decade of Experimental Music was organized by the Groupe de Recherches de Musique Concrète in Paris in June 1953. It was an attempt to unite the contemporary music world under the banner of experimental music, but whose experimental music? Given that there was even a schism within GRMC between composers like Pierre Boulez, who thought that technology was merely a means for the improvement of the serial tradition and Schaeffer and Henry, who were trying to come to terms with some sort of conceptual framework for the organisation of musique concrète (as opposed to being merely a method of transforming sounds). Schaeffer was later to publish his ideas in an article titled "Vers une musique experimentale" (Schaeffer 1957).

Some years earlier (1951) Schaeffer and Henry had embarked on the creation of a concrete opera *Orphée* (1951-1953). The combination of song and tape music was "considered a scandal at its performance at Donaueschingen in (October) 1953, as if it had been a crime of high treason against the avant garde".[3]

After the Decade festival and the controversy of the *Orphée 53* performance, Schaeffer distanced himself from the GRMC to direct the foundation and management of Radiodiffusion de la France d'Outremer – the international arm of the French broadcaster.

As Gayou notes, there was also some resentment, by Schaeffer, of the success being enjoyed by Pierre Henry and Philippe Arthuys. So much so that, when Schaeffer

[2] Gayou (Gayou 2007, 203) quotes Schaeffer from his book Pierre Schaeffer, 1951, *A la recherche d'une musique concrète*. In the first part of this book, Schaeffer recounts its invention in the form of a diary

[3] As described by Michel Chion in the notes (pp. 55-56) to Schaeffer's compilation CD set, see Schaeffer (1998)

returned to the GRMC in 1957, he forced them to resign and he restructured the research group into the Groupe de Recherches Musicales (GRM). "A few months later, Schaeffer recruited his new collaborators: Luc Ferrari, Iannis Xenakis, Bernard Parmegiani, Mireille Chamass-Kyrou, François-Bernard Mâche. Later arrived Ivo Malec, Philippe Carson, Romuald Vandelle, Edgardo Canton and François Bayle." (Gayou 2007, 207)

With the new GRM, Schaeffer had withdrawn the term musique concrète, with its aesthetic connotations, and he started defining his work as music research. He returned to the studio and composed a new set of studies. In 1960 he established a broader research department with himself as head. It included the GRM along with the Groupe de Recherches Image GRI, the Groupe de Recherches Technologiques GRT and the Groupe de Recherches Langage which became the Groupe d'Etudes Critiques. In 1966, Schaeffer published his treatise on musical objects, the *Traité des Objets Musicaux* (TOM) – the summation of all his work. "The Solfége de l'Objet Sonore came out in the following year and consisted of three LPs of sonic examples that served to illustrate the *Traité*." (Gayou 2007, 207-208)

Schaeffer left the running of GRM to François Bayle while he concentrated on Le Service de la Recherche until its replacement by l'Institut National de l'Audiovisuel in 1975, when Schaeffer was forced to retire at the age of 65.

In summary, we can track Schaeffer's ideas and activities from radiophonic art to noise studies, musique concrète and experimental music. From the detached sound object to a new interpretation of the note, instrument, and context for expression (the concert). The mantra of "listen then do" was used throughout the history of both the GRMC and GRM. A comprehensive solfège of the sound object was combined with a theoretic framework expressed in the TOM publication. With each idea, and at each stage, new technologies were embraced as fresh enablers. The notable exception, for Schaeffer, was the digital computer, which he regarded as an obstacle between the composer and music making. With this historical, conceptual and organisational background in place, we will take up the topic of technology in the next section.

3. GRM TECHNOLOGIES

3.1. Musique Concrète Concepts

In the first decade of GRM there are concrete sounds (re-modelled[4]), instrumental sounds (re-modelled), and a short time later, electronic sounds being used. The introduction of electronic sounds coincided with a relaxation of the initial strong rules surrounding early musique concrète to "…leave place for a more free and personal way of using sounds, for which every composer designs his personal contour" (Teruggi 2007, 214)

Whatever the source, the notion of structuring of various sound objects must be achieved through listening and derived by abstracting formal structures from the source materials themselves, as opposed to superimposing an 'a priori' musical system on the materials. This was the fundamental difference between Schaeffer's approach and it put him at odds with the method employed by the serial composers, like Pierre Boulez, who were a dominant force in the 1950s.

With the Schaefferian approach, there was a need for new tools to modify and manipulate sounds to heighten abstraction: "…with the objective of producing sounds that will be perceived primarily as forms and structure and less as anecdotes or language references. Instrumental sounds can be combined; however, concrète sounds have to be modelled before being combined." (Teruggi 2007, 214) It is also important to realise that any tools that are used will leave their own traces that can be heard by the ear. But what were these tools?

3.2. Technological Periods

In his article in the Computer Music Journal, Teruggi breaks up the history of technology in GRM into four main periods, the first of which pre-dates the GRM (Teruggi 2007, 215):

- Mechanical period: 1948 - 1960.
- Electronic period: 1960 - 1970.
- Digital mainframe period: 1970 - 1990.
- Personal computer period: 1990 – present day.

3.3. The Mechanical Period

Around 1948, Pierre Schaeffer's studio comprised a shellac record recorder, shellac record players, a mixing desk, mechanical reverberation unit, several kinds of filters, and microphones.

This equipment afforded the following musical possibilities: sound transposition by playing recordings at various speeds; playing forwards and reverse; sound looping by creating a continuous groove in a shellac record; sample extraction by selecting a particular part of a record; filtering to change the timbre; mixing sounds by recording from the mixer; and creative microphone techniques to capture different aspects of a sound making object.

Tape recorders arrived in 1949, but were initially found to be less reliable than shellac players: "…to the point that the *Symphonie pour un homme seul*, which was composed in 1950–51, was mainly composed with records, even if the tape recorder was available" (Teruggi 2007, 216).

[4] "Modelling" a sound is the process by which filtering, transposition and microphone placement erase the source reference and retain essential information for musical use.

Around 1950, Schaeffer elicited the help of technician Jacques Poullin to create new machines that were derived from the tape recorder. Two types of phonogène (sound generator) were created in 1953 to allow pitch transposition of recorded material. The chromatic phonogène had a one octave keyboard and 12 reading heads associated with capstans of different sizes. The 12 possible speeds permitted transposition by 12 different pitches. The sliding phonogène made continuous speed variation, and therefore glissandi, possible.

3.4. The Electronic Period

The widespread availability of the transistor in the late 1950s led to a lot of development in electronics. The modular synthesizer was one of such inventions. Although recording sounds was the focus at GRM, Pierre Henry had started using oscillators to produce sounds as early as 1955. But the emerging synthesisers meant parameter control, which was against Schaeffer's philosophy of "making through listening" (Teruggi 2007, 219).

However, a project for the development of the Coupigny synthesiser was initiated. It was created under Schaeffer's influence where "parameters would be globally controlled without actually permitting a very precise definition of their values" (Teruggi 2007, 220). Thus it functioned more as a sound event generator rather than a precision musical instrument.

The Coupigny synthesiser included the major components of a modular synthesiser that could be easily interconnected: oscillators, noise-generators, filters, ring-modulators, with facilities for frequency modulation, amplitude modulation, and external source modulation. It had a complex envelope generator, but no keyboard was attached. Thus it could produce extremely complex sounds, but it was less suited to producing precise frequencies or triggering sounds in a sophisticated way. "The typo-morphological concepts of Schaeffer were clearly applied here." (Teruggi 2007, 220)

The Coupigny synthesiser breathed new life into the GRM composers and many GRM masterworks were composer from 1969 to 1975, including the classic *De natura sonorum* by Bernard Parmegiani (1974-75), which used concrete sounds, instrument sounds, and synthesiser sounds in an interwoven fabric that was carefully crafted.

3.5. The Mainframe Computer Period

Jean-Claude Risset had been collaborating with Max Mathews at the Bell Laboratories since 1964. Risset brought some of the first works calculated by main frame computer to France, along with the software synthesis language Music V. A group of young GRM researchers were interested but Schaeffer was sceptical about computers since they required a pre-conceptualisation of a musical work. Teruggi relates a critical turning point for Schaeffer and GRM in 1970:

> An international conference on computer music took place in 1970 in Stockholm, fostered by Unesco. Many of the leading researchers in the digital domain were present at the meeting, including Mathews, Risset, Zinovieff and Schaeffer as a kind of historical reference. During this meeting Schaeffer gave a speech and participated in a roundtable discussion, where he was extremely critical towards computer-generated sounds and their eventual use in electroacoustic music. Participants at the conference were quite shocked by the conservative attitude of one of the inventors of technological music and the consequences were a certain isolation of the GRM from the digital actors. (Teruggi 2007, 220-221)

The GRM technical team was disappointed by this attitude and decided to explore two avenues simultaneously. The first team saw a way forward with the development of possible real-time synthesis solutions, which would still enable a composer to interact with sound materials directly. The second wanted to understand how the Music V software could be applied to musique concrète.

Real-time synthesis was very difficult using computers at this time, and there were several attempts. One project started as a collaboration between Knut Wiggen from EMS in Stockholm and the GRM. Christened Syntom from SYN(thèse) + T(raité) des O(bjets) M(usicaux) (synthesis based on the treatise of musical objects). It took as its starting point the concepts expressed by Schaeffer in the *Traité.* Attempting to create typologies and morphologies with buttons would prove too difficult, and the project failed.

Meanwhile, the team of Pierre-Alain Jaffrennou, Benedict Mailliard experimented with Music V towards a GRM-based way of composing. Then in 1974, a young engineer by the name of Jean-François Allouis arrived. The invention of smaller, faster chips meant that faster parameter control was becoming feasible and the notion of hybrid synthesis controlled by such chips was making real-time systems possible. The Syter Project started in 1975 with Syter signifying firstly 'real-time synthesis' then later 'real-time system'. The first prototype was used in 1977.

In 1978, GRM acquired its own mainframe computer, running Music V. A PDP 11/60 mini-computer was also installed with its own digital-to-analog converters. The team was located in Studio 123 at Radio France, and developed models for action on sound in software.

3.6. Transition to Real-time and the SYTER Project

Slowly the work of the Studio 123 team and Allouis' real-time work came together and the first fully operational Syter system was finished in 1984.

The Syter system was comprised of modules such as oscillators, envelopes, delays, harmonisers, and noise-generators. These modules were able to be inter-connected with each other and with an innovative set of sound processors. Many of these were derived from the models developed by the Studio 123 software synthesis group. Teruggi lists some of these processing instruments and includes their corresponding name in the GRM Tools set. (Teruggi 2007, 226) It also had a graphic interface

controlled through a mouse, thus permitting real-time control of the parameter variation and a MIDI interface.

3.7. Personal Computer Period - GRM Tools

Hugues Vinet, replaced Jean-François Allouis in 1988, and started experimenting using the new Apple Macintosh with the Digidesign Sound Designer card, which had become available then. Using this system, the first version of GRM Tools appeared in 1991. Although constrained by a reduction in processing power, and therefore a step back from the Syter system, it provided broader access to the software tools.

Emmanuel Favreau continued the development in 1994 by adapting GRM Tools to new environments. Teruggi notes:

> A first series of eight algorithms was launched called Classical bundle, which was mainly an adaptation of the Studio 123 and Syter models to the new environments, with improved graphical controls and performances, and sometimes with new possibilities. (Teruggi 2007, 226)

GRM Tools ST followed, allowing spectral processing and analysis-synthesis methodologies.

3.8. Summary of GRM Technology Concepts

At GRM, a set of operating categories had evolved over the years and were given the name 'morpho-concepts' by Hugues Vinet and François Bayle in the early 1990s. In a way, these concepts unite much of the technology from the 1950s onward. Teruggi lists[5] them as: Sound isolation and observation; Sound editing; Sound addition; plus the following "modifications": Dynamic; Speed; Time; Spectral; Density; Order of events; and Space. (Teruggi 2007, 229)

Teruggi also cites three trends that have influenced every research and development team at GRM. In other words, these are the basic design principles underpinning all of the technical developments at GRM (Teruggi 2007, 229):

1. Tools are made to be controlled through listening and during listening. The basic concept issued from the 'making' and 'listening' duality by Pierre Schaeffer.
2. Tools should be easy to grasp and manipulate.
3. The user should be independent and not rely on an external operator.

4. NES-TOOLS

4.1. NES-Tools overview

Inspired by the GRM Tools suite of audio processors, this project set out to create a set of processing tools using Cycling 74's Max environment. The idea was to just use only the standard objects that come with Max 7/8, however many of the tools I wanted to create had already been implemented in one form or another in the standard distribution files and examples. What I have done in this project is to adapt and add to the examples created by others, and then assemble these tools into their own suite. The NES-Tools suite is summarized in Table 1, with the corresponding GRM Tools Classic equivalent in italics.

NES-Biquad~ *Bandpass*	Implements a two-pole two-zero filter (for 2 channels)
NES-Brassage~ *Shuffling*	Granulate a sound loaded into the device itself
NES-CombFilter5~ *Comb Filter*	Implements 5 Comb filters
NES-DelayTaps~ *Delays*	Up to 32 delay taps
NES-DopplerPan *Doppler*	Simulate a Doppler effect
NES-PitchMulti~ *PitchAccum*	Multiple pitch shifters with vibrato & feedback
NES-Reson~ *Reson*	Up to 32 simultaneous resonators

Table 1. NES-Tools suite of transformations.

4.2. NES-Tools Overview Patcher

To use the NES-Tools suite, the file 01-NES-Tools-Overview.maxpat provides a quick way for the user to try each tool by running the patcher in Max and clicking on the relevant title (See Fig. 1). Make sure you close a patch before opening another one, to avoid any confusing conflicts.

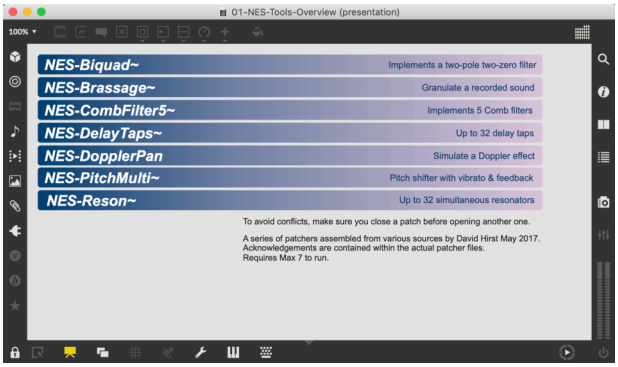

Figure 1. The NES-Tools Overview patcher[6].

4.3. NES-Tools details

Except for the special case of NES-Brassage~, each of the NES-Tools is set out in the same way. Figure 2 shows NES-Biquad~ and its structure is set out from top to

[5] Only their headings are listed here. See the Teruggi (2007) article for a full explanation of each

[6] Note that the screen shots in this article depict the general layout only. For detailed views, download the NES-Tools suite from https://davidhirst.me/software/ and run the patchers using Max 8 from https://cycling74.com

bottom. At the top is a section where you load a sound file. In the middle section there are the controls for the relevant processor. At the bottom of the patcher is a section that enables the user to adjust the playback gain and to record a sound file of the processed sound. The user can then quickly load and audition the recorded sound file.

Here are more specific details for each tool.

NES-Biquad~

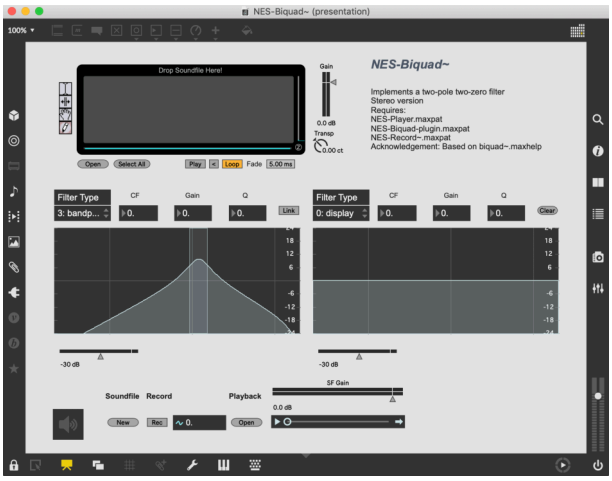

Figure 2. NES-Biquad~

NES-Biquad~ (Fig. 2) is based on biquad~.maxhelp and implements a two-pole two-zero filter (for 2 channels). Change the filter type, frequency, gain and Q for two channels independently, or use the 'Link' switch to allow the left controls to apply to the right channel simultaneously.

NES-Brassage~

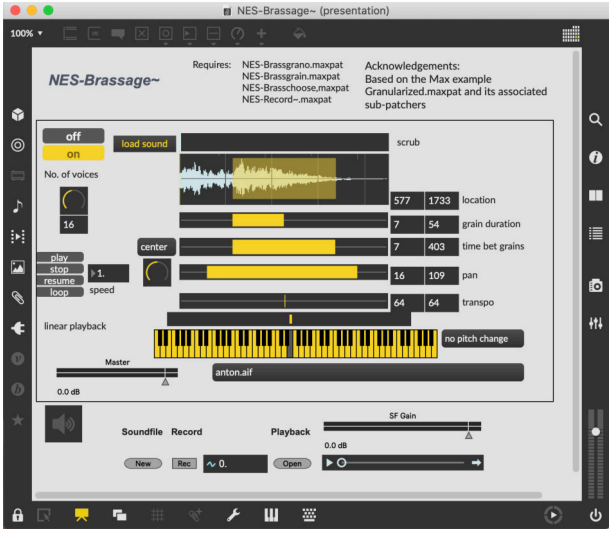

Figure 3. NES-Brassage~

NES-Brassage~ (Fig. 3) granulates a recorded sound, and is based on the Max example Granularized.maxpat and its associated patchers.

The user loads a sound file and clicks 'on' to start granulation, then either selects a section in the waveform view, or presses play or loop to provide the source for granulation. The granulation parameters can then be varied.

Controls are for: grain location within the source file; grain duration; time between grains; pan position; and pitch transposition. A range can also be set for all of these parameters, within which random values are constrained.

Other controls are the number of granular "voices" or simultaneous grains; the speed of playback of the source file; scrubbing the source file; and overall gain. The resultant sound can be recorded.

NES-CombFilter5~

Figure 4. NES-CombFilter5~

NES-CombFilter5~ (Fig. 4) implements 5 Comb filters, and is based on based on the CombFilterMulti Max for Live plugin. There are controls for pitch; detune; and feedback for each of 5 bands, plus input gain; feed-forward; transposition; tremolo; dry/wet; and an output gain. A frequency display completes the tool design.

NES-DelayTaps~

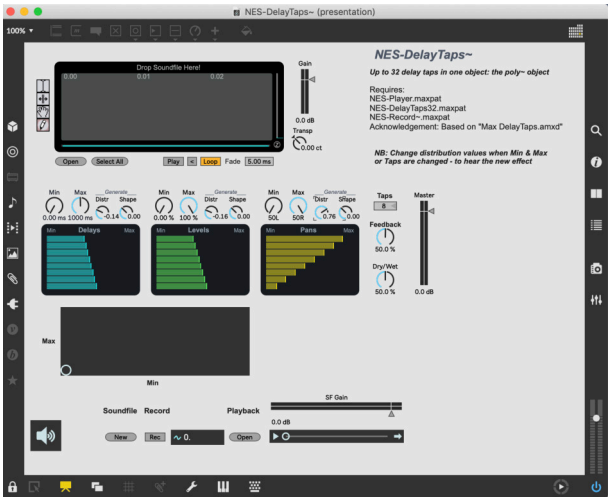

Figure 5. NES-DelayTaps~

NES-DelayTaps~ (Fig. 5) implements up to 32 delay taps. The tool is based on a modified version of Max DelayTaps.amxd, distributed with Max 7. There are controls for delays; levels; and pans for up to 32 separate

delay lines. Each of these parameters has its own controls for min/max, distribution and shape and an editable display of their values. The X-Y controller allows you to change the min/max delay amounts simultaneously. Also vary the number of taps, overall feedback, dry/wet, and master gain.

NES-DopplerPan

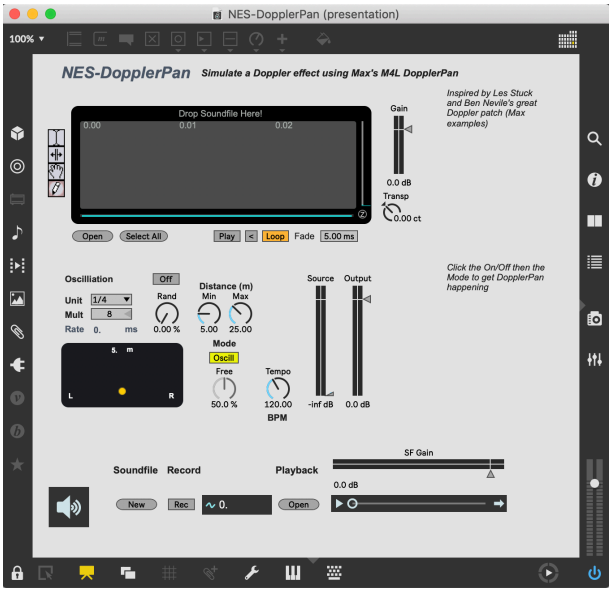

Figure 6. NES-DopplerPan

NES-DopplerPan (Fig. 6) simulates a Doppler effect and is a modification of Max for Live's DopplerPan, which was inspired by Les Stuck and Ben Nevile's Doppler patch (from the Max examples). The user clicks the On/Off, then the Mode, sets the min/max distance, decides on the degree of randomness, etc. The pan oscillation can be synchronised with a tempo.

NES-PitchMulti~

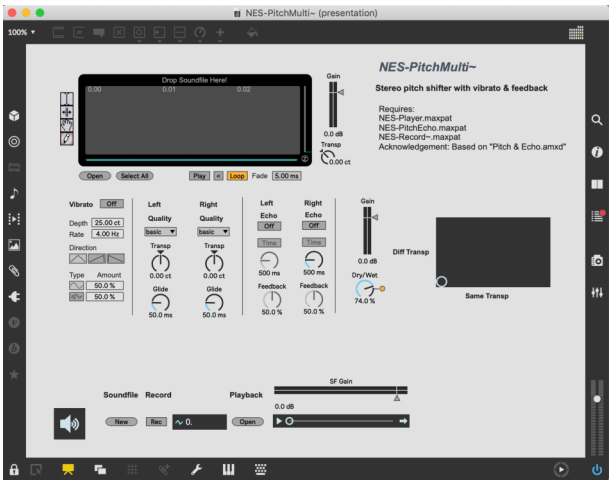

Figure 7. NES-PitchMulti~

NES-PitchMulti~ (Fig. 7) pitch shifts with vibrato and feedback, and is derived from Pitch & Echo.amxd, distributed with Max 7. The X-Y controller allows you to change the transposition amounts for each channel simultaneously.

NES-Reson~

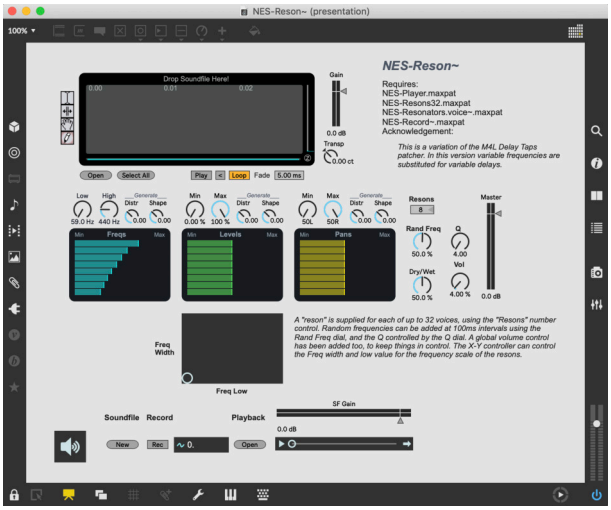

Figure 8. NES-Reson~

NES-Reson~ (Fig. 8) implements up to 32 simultaneous resonators. It is a variation of the Max for Live Delay Taps patcher where variable frequencies are substituted for variable delays. Random frequencies can be added to the resonators, and the Q is controlled by its own dial. A global volume dial has been included to keep the Q under control, plus there is a dry/wet dial and a master fader. The X-Y controller allows the user to simultaneously change the lower frequency value and the difference between this lower value and the upper value for the range of resonances.

4.4. NES-Tools Abstractions and Extensions

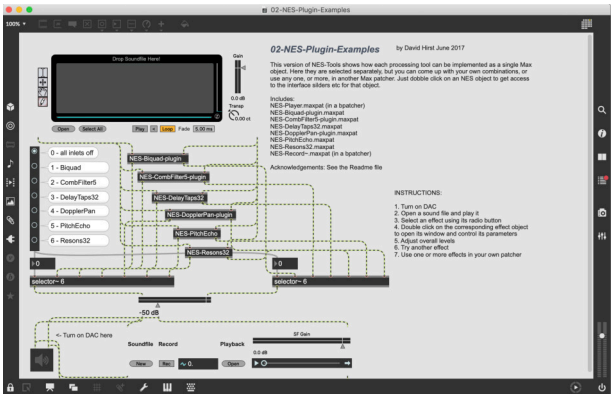

Figure 9. 02-NES-Plugin-Examples.maxpat

All of the tools (except NES-Brassage~) implement their processing as a separate patcher, and can therefore become their own object in Max. This is known as "abstraction" in Max. The user can create her/his own master patcher that could string a series of processes together in the one patcher. 02-NES-Plugin-Examples.maxpat provides one example of how this can be done (Fig. 9). In the example the user can open a sound file and play it; select an effect using its radio button; double click on the corresponding effect object to open its UI window and control its parameters; adjust overall levels; try another effect; and use one or more effects in their own patcher.

4.5. NES-Tools - Max for Live Versions

In a recent development, NES-Tools has been written as a suite of plugin devices for Ableton Live, mostly as "Max Audio Effects".

NES-Brassage02.amxd (Fig. 10) is implemented as a Live "Max Instrument" and has been specially programmed to allow for multiple instances in Ableton Live, as have all the above devices.

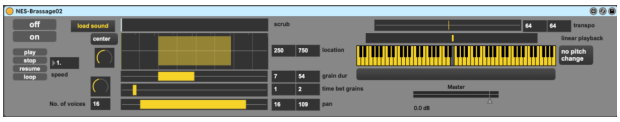

Figure 10. NES-Brassage02.amxd

5. EXAMPLE OF COMPOSITIONAL USE

As a final test, the NES-Tools have been used, along with the NES-Spectrale suite, MUBU and spindrift~ to create the 15 minute work *The Portuguese Suite*[7], performed in its eight channel version at ACMC 2019.

Note that the resultant final sounds within the work are a combination of many processes, but here are some selected example passages from the recording that the reader can find via the Soundcloud link (See Table 2 and the footnotes).

00:00 – 00:58	Uses NES-Reson~ to elongate the bell sounds
00:56 – 03:02	NES-PitchMulti~ combined with interpolation of bells
01:58 – 03:56	FFT screening FX of bells from NES-Spectrale
03:55 – 05:12	Transformed clapping from NES-Spectrale
05:14 – 07:48	Uses the Playtwo effect from NES-Spectral
07:50 – 10:45	Uses the CataRT & Mosaic FX from IRCAM's MUBU suite[8]
09:48 – 14:16	Combined FX of NES-Spectrale variable playback, NES-Biquad~ & other filtering, & the spindrift~ object by Michael Norris[9]

Table 2. Selected examples of tool use in *The Portuguese Suite*.

[7] The Portuguese Suite can be listened to at https://soundcloud.com/david-hirst-1/portuguese-suite

[8] MUBU is available from the IRCAM Forum https://forum.ircam.fr/projects/detail/mubu/

6. CONCLUSION AND FURTHER DEVELOPMENTS

The virtue of NES-Tools is that the suite provides a GRM-Tools-like set of audio processors within the Max environment. That means the patchers can be used, as they are, with the free Max version in "non-saving mode", or they can be edited and extended by the user with a paid copy of Max. NES-Tools written as Max for Live devices are also free from the author's website.

Future developments will explore the use of presets and the recording and storage dynamic controls. Custom configurations of NES-Tools can also be used as live performance instruments, encouraging improvisational uses.

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[9] Spindrift~by Michael Norris is available here: http://www.michaelnorris.info/software/spindrift

SYNESTHETIC: COMPOSING WORKS FOR MARIMBA AND AUTOMATED LIGHTING

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ABSTRACT

This paper describes a series of explorations aimed at developing new modes of performance using percussion and computer controlled lighting, linked by electronic sensing technology. Music and colour are often imagined to be related and parallels have been drawn between the colour spectrum and keyboard. Some people experience a condition, chromesthesia (a type of synesthesia), where experiences of colour and sound are linked in the brain. In our work, we sought to explore such links and render them on stage as part of a musical performance. Over the course of this project, tools and strategies were developed to create a performance work consisting of five short movements, each emphasising a different interactive strategy between the performer, lights, and composition. In this paper, we describe the tools created to support this work: a custom wearable lighting and sensing system, and microcontroller based OSC to DMX lighting controller. We discuss each composition and how the interactions reflect ideas about synesthesia.

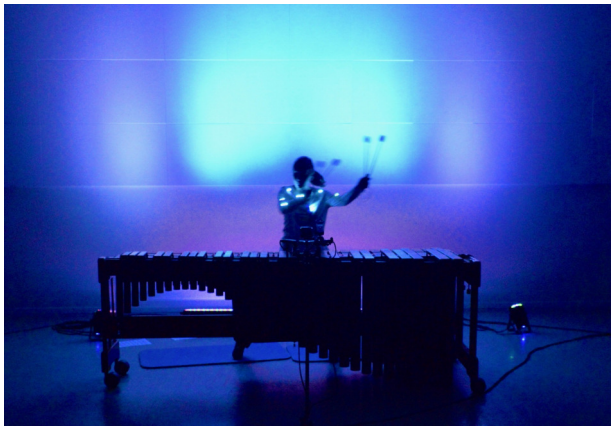

Figure 1. The performer playing one of the works in *Synesthetic*. The stage was dark except for computer controlled lighting on the rear wall and a wearable lighting system on the performer's shirt. Videos of this performance can be found here: https://doi.org/10.5281/zenodo.3402419

1. INTRODUCTION

Music has long been associated with colour (Peacock 1988). The word "colour" is commonly used to describe multiple aspects of music–the tone quality, the mood of a piece, the type of instrumentation. Artists often attempt to depict their experience of music in their visual works (McNamara 2009). Synesthesia is a neurological condition in which stimuli trigger one or more additional senses (Hubbard and Ramachandran 2005). These experiences can affect any sense, for example, in lexical-gustatory synesthesia words stimulate taste responses (Banissy et al. 2014). Some individuals with synesthesia experience colours when they hear sounds; this is known as chromesthesia (Rogers 1987). Since this phenomenon became recognised it has been of interest to composers, leading to the development of a "clavier à lumières" (colour organ) by Alexander Scriabin in 1915 (Peacock 1988) which projects light onto walls when its notes are played. In 1919, German film director Walter Ruttmann predicted that technological advances would increase the amount of connections between sound and images in art, resulting in a "constant state of being swamped with material" (McDonnell 2007). While this has not occurred, we have seen several modern attempts at integrating sound and visual material, such as the interactive installation LINE, a three dimensional interface that emits sound and corresponding light (Kobori et al. 2006).

This project, called *Synesthetic*, focused on chromesthesia. The French composer Olivier Messiaen "suffered" from chromesthesia, as Messiaen explained to the French critic Claude Samuel in 1988: "I see colours when I hear sounds, but I don't see colours with my eyes. I see colours intellectually, in my head." (Ballard et al. 2017). While few synesthetes experience the same correlations between sound and colour, individuals have consistent associations in their own experiences (Sacks 2007). One synesthete has described his music-triggered colour experiences as having "... a sort of transparent, luminous brilliance... like a screen before him" (Sacks 2007). To imitate this experience, we experimented with new modes of performance and composition for percussion, coloured lights, and sensing (shown in Figure 1). The senses of hearing and vision are inextricably linked for synesthetes, and so we wished to create a connection between sound and visuals that was aesthetically pleasant and not jarring; a matching that was complementary rather than just added-on.

For this project, we created a system where instead of

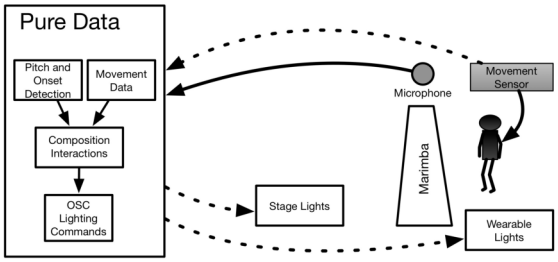

Figure 2. Our performance system included wearable and stage lighting, a motion sensor, and audio tracking of the marimba sound.

automatic projection of light when a key is pressed (as in the colour organ), we used a Pure Data patch on a computer to listen to the notes on an acoustic marimba, recognise pitches and note onsets, and then respond appropriately with a coloured LED light. Percussion performance has been defined by the gestures percussionists use to create sound (Schick 2006, p. 5) and the ancillary movements that do not affect sound, but nevertheless shape how it is perceived (Schutz and Manning 2012). With respect to this, we also used motion sensing to create a connection between the movement of striking the marimba, sound and light.

We created five interaction environments in which the lights would respond differently to the sound of the marimba and the movement of the performer. Our composer wrote five short pieces that demonstrate and explore each interaction. We developed this work during a five-day artistic residency, creating one new interaction environment each day, and a composition on each of the first four days. We performed these four pieces and one improvisation to a small audience who were able to give feedback after the performance.

2. SYSTEM DESIGN

In this section we describe the design of our performance system. This consisted of wearable lights, sensors, and our computer controlled stage lighting system. These systems were coordinated by a laptop running Pure Data, where we were able to experiment with different interactions during development. Our Pure Data program also ran pitch tracking and onset detection on the marimba sound, which was used for different interactions in our compositions. There were no electronic sounds in our project. A summary of our system design in shown in Figure 2. Source code and parts lists for our setup are available on our GitHub repository: https://doi.org/10.5281/zenodo.3392870.

2.1 Wearable Lighting

Our wearable lights and sensors used Wemos D1 Mini Lite systems, internet of things (IoT) prototyping boards based on the Espressif ESP8285 microcontroller. These small and inexpensive boards can be powered by a USB battery and include WiFi connectivity, and programming capabilities similar to an Arduino microcontroller. This

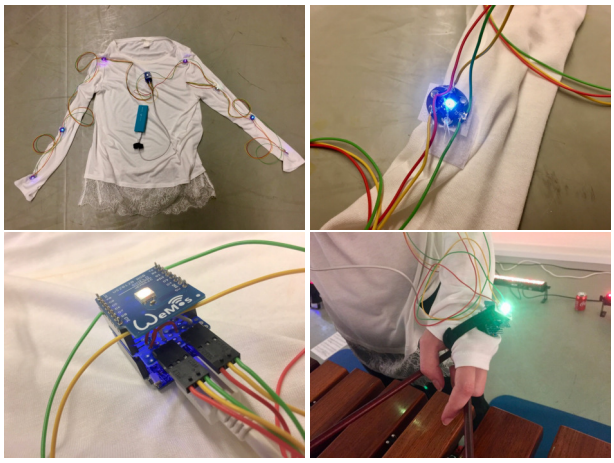

Figure 3. Detail of our wearable lighting system installed on the performer's costume (top and bottom left). Motion sensor attached to the performer's hand (bottom right). The RGB LED modules were controlled by a Wemos D1 Mini Lite microcontroller board.

prototyping platform is comparable to those used in previous research using the ESP8266 module (Ferguson et al. 2017) and XBee wireless system (Baalman 2017).

The wearable lights included one Wemos D1 Mini on the performer's chest (see Figure 3) connected to nine RGB LED modules (WS2812 breakout boards a.k.a. "neopixels"). The LED modules were backed with velcro and could be attached in various ways to the performer's costume during our project development. The costume consisted of a plain white long-sleeved t-shirt, altered to have thumb holes to keep the sleeves more secure. Velcro loop squares were hand sewn to the shirt to accommodate the LEDs and microcontroller module. The lights were positioned at the upper wrists, elbows, upper arms, shoulders, and one attached to the microcontroller in the centre of the chest. A USB battery to power the microcontroller was held in the performer's pocket.

2.2 Movement Sensor

Another Wemos D1 Mini Lite was used as a wearable movement sensor. A small accelerometer breakout board (ADXL345), was attached to the microcontroller, and this system attached to the performer's hand with velcro strips to sense percussive gestures (see Figure 3). For our work, we experimented with using the accelerometer readings as well as the simple "tap" gesture, recognised on the accelerometer chip, to drive aspects of the sound/light interactions.

2.3 Lighting Controller

For project development and our initial performance we used a set of low-cost RGB LED lighting bars and developed a custom solution for controlling them via their DMX interface. We were inspired by an Arduino-based lighting controller[1], which included a wired network connection for input, DMX output, and a 3D-printed enclosure.

[1]https://github.com/alfo/artnet

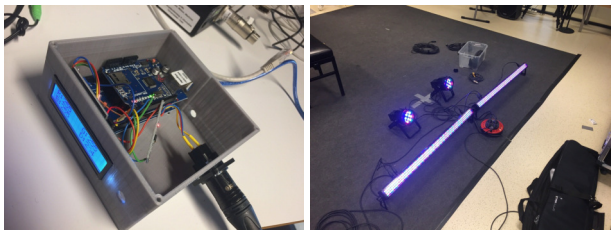

Figure 4. Our OSC to DMX lighting controller (left) and our experimental stage lighting rig (right).

For our project, we used a similar controller design, using an Arduino, Ethernet shield, and a MAX485 breakout board for interfacing via DMX (see Figure 4). We developed firmware for our use-case that could respond to OSC messages and used an edited version of the 3D-printed enclosure. In future, this controller could be replaced by a more refined system that communicates over WiFi rather than wired Ethernet.

2.4 Stage Setup

Our stage for the premiere performance was a large dance studio with white walls. We positioned the marimba approximately 1.5m away from a wall, facing into the centre of the room. The lights were positioned on the floor so that they shone onto the wall behind the performer. The performer was able to see some of the ambient light reflected on the marimba in concert lighting conditions. Our computers were set up to the side, out of the direct line of sight of the audience and performer. There was no additional stage lighting.

3. COMPOSITION

After developing our wearable and stage lighting systems, we developed five sketch compositions for Synesthetic during an intensive five-day workshop. Each of these sketches explored different interactions between lighting and sound and featured contrasting musical material. The following sections describe each of these works.

Videos of each work can be found online at https://doi.org/10.5281/zenodo.3402419.

3.1 Connecting Sound to Colour

In the first session, our aim was to use a simple sound-to-light interaction in a composition. We divided the colours red, green and blue across the entire range of the marimba. The lowest pitched notes of the marimba were mapped in Pure Data to trigger blue lights, the middle range mapped to green and the highest mapped to red. The colours blended when notes were played between these pure colours, blending red with green in the upper middle register and blending green with blue in the lower middle register. The composition written for this session made use of this blending and changing of colours. This led to some unusual jumps between very high and very low notes (see Figure 5). The lowest octave of the marimba has strong, clear overtones, and we found that these led to misclassification in our pitch tracking patch and caused the lights to flash between red and blue. We attempted to eliminate this flashing effect by adjusting the position of

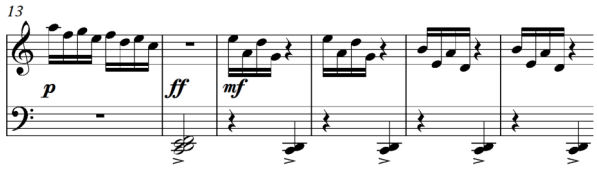

Figure 5. An excerpt from the score of session 1 showing the marimba jumping from the high range to the low range of the marimba.

microphone and changing to softer mallets. Softer mallets did produce more of the fundamental tone, but can be too soft to properly play the higher notes. In our performance, we compromised on a medium-soft mallet which made the high notes audible when played with some force, and did not produce too many interfering overtones in the lower register.

3.2 Designing a Twelve-Tone Colour-Scale

For this composition we focused on connecting pitch classes to individual colours. Some have attempted to assign each tone to a colour, matching frequencies to positions in the colour wheel, Well's work is one example (Wells 1980). However Wells' proposal is not the experience of most synesthetes. Instead of using this kind of ordered rainbow approach, our tone-to-colour mappings was borrowed from Scriabin's 1910 work *Prometheus: The Poem of Fire* (Op. 60) where the score indicates how certain colours should fill the stage. Although Scriabin was probably not a synesthete in the clinical sense (Galeyev and Vanechkina 2001), he felt strong connections between colour and sound. Our attempts to replicate Scriabin's mapping were frustrated by the colour reproduction ability of our LED stage lights; however, we were able to find a set of twelve similar colours such that the contrast between each tone was discernible.

This composition is a twelve-tone work, where the tonal material comes from the first 8 bars of the development section of the fourth movement of W.A. Mozart's Symphony No.40 in G minor, K.550.

3.3 Communicating from Colour-Scale to Performer

Sacks describes a synesthete who sees a pane of yellow glass and is reminded of the key of B flat major (Sacks 2007). This indicates that synesthesia can go both ways—from music to colour and the reverse. For session three, we intended to use Scriabin's colour-tone association from the previous session in an inverse manner: to communicate instructions to the performer. We programmed a series of colours to illuminate the costume, to instruct the performer which note to play using the 12-tone colour scale. This required the performer to memorise the series of colours in the scale (see Figure 6). In practice, we found that it was almost impossible to discern several of the colours when trying to "read" them in this way. In particular, the lights did not make clear greys or browns. We attempted to overcome this problem by changing several note colours to be more easily distinguishable. It was necessary for the composition to be monophonic and slow to allow the performer to discern the colour, find the correct

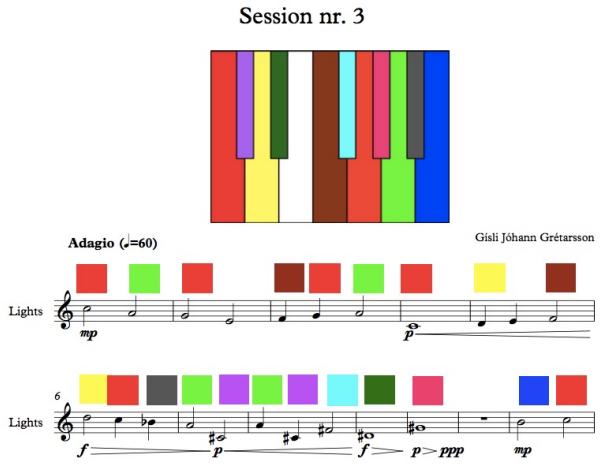

Figure 6. An excerpt of the score for session 3 (not shown to the performer), showing the notation as well as the associated colour. Also shown is our modified 12-tone colour association keyboard

note, and play.

To add an extra dimension to the challenge of this work, the wearable lights were set to indicate the score to the performer, and the background lights react to show the actual notes played. The audience watching could then tell if the performer played a wrong note by seeing a difference between the colour on the costume and the colour on the background wall. It was still very difficult for the performer to correctly discern some of the the notes based on the lights on the costume. For instance, blue and purple, and dark green and light green, were easily confused. This limitation could be due to the colour reproduction of our lighting setup and we hope that further experimentation with different stage lights may lead to more reliable communication. Despite the limitations of the setup in the performance, audience members enjoyed this piece due to the clear and visible interaction between performer, composition, sound, and light.

3.4 Indicating Tonality with Colour

One synesthete has described seeing colours associated with keys, chords, and tonalities rather than individual notes (Sacks 2007). The person had over 24 different colour associations with the different keys and modes. To mirror this association, a composition was created that had several distinct key changes throughout. During the performance of the piece, a matching sequence of colours was displayed on the stage lights at the key changes (see Figure 7). This lighting change was triggered manually by the composer. The lights on the costume corresponded to the notes actually being performed, using the tone-colour keyboard we designed in the previous session. Although this session was the simplest in terms of interaction, feedback from audience members suggested that they found this piece to be relaxing and interesting.

3.5 Connecting Motion to Light

Percussion can be defined by performance gestures, the motion of striking an object, rather than any particular instrument (Schick 2006). In the fifth session we experimented with connecting data from our motion sensor to light. We were able to develop a simple method for inferring strike gestures by detecting high aggregated acceleration of the performer's hand. We used such strike events to temporarily light up the performer's costume with a white light which subsequently faded to mirror the marimba's sound envelope. This connection was quite compelling as the costume lights flashed in rhythm with the percussionist's left hand. As this was the final session, a composition was not completed in time to receive feedback at the open rehearsal evening. Instead, a short improvisation was performed which adequately demonstrated the interaction between movement and light.

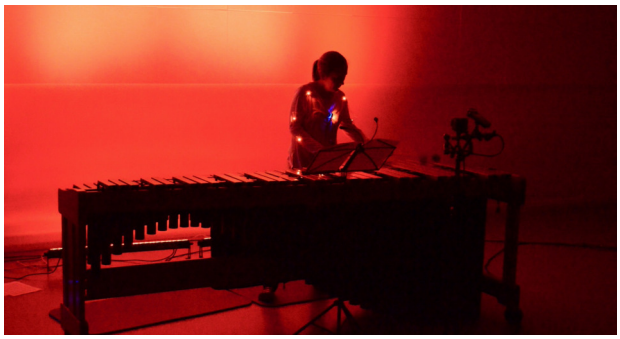

Figure 7. An image from Session 4, where tonality was connected to colour.

4. CONCLUSIONS AND FUTURE WORK

The aim of this project has been to explore real-time connections between sound and light in marimba performance, inspired by real and imagined concepts of "synesthesia". In this paper, we have described the interactive music systems we developed to explore such connections. These included wearable lighting and motion sensing systems, a custom DMX lighting controller, and audio analysis Pure Data patches. We have also described a series of five interactive environments using this setup, and compositions written to explore these environments. These systems, compositions and interaction studies allowed us to play with the connection between sound, light and marimba gesture, and could serve as a basis for future performance setups and compositions.

Our development process uncovered some issues that complicate the goal of directly connecting sound and light. In the first two sessions, inaccuracies in pitch tracking led to a lack of stability in light colours. It may have been more accurate to use a MIDI instrument to map the notes to certain lights and vice versa; however, it could be that the confusing overtones of the marimba and flashing effects is what a synesthete might experience. We do hear those overtones, and they define the timbre of the note. We feel that such interactions between sound and light imitate what some synesthetes may experience when listening to music, although it was not possible to provide a fully immersive experience with our limited setup. While the connections we have made make artistic sense, we suspect that it may be jarring for actual synesthetes to view

our performance, as the projected lights may not match their own experience of synesthesia. In future, we aim to expand this project to a concert-length program of composed music and lighting interactions, or expanding the artistic goals by adding more musicians or a dancer.

Acknowledgements

This work was partially supported by Arts Council Norway.

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SISTERS AKOUSMATICA'S 'EXPANDED RADIO' PRACTICE AS RADICAL FEMINIST BROADCAST

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ABSTRACT

Sisters Akousmatica is a collaborative transmission arts project launched by Tasmanian sound artists Phillipa Stafford and Julia Drouhin in 2016, concerned with 'promoting women and gender diverse voices in public space' (Sisters Akousmatica, 2019a). Their practice involves large scale public transmission projects, hidden radio broadcasts, transmitter building workshops with women and children, and written research, exploring the potential of emergent art forms to support, promote and cultivate socio-cultural and gender minorities in the field of sound arts. This paper investigates the 'expanded radio' medium (Sisters Akousmatica, 2019a) and how it may enable *Sisters Akousmatica*, women and gender diverse folks to reimagine the cultural space of radio through alternative discourses. I approach analysis from a feminist musicological framework, informed by theories of Susan McClary and seminal feminist theorist Hélène Cixous. Considering the paucity of empirical and theoretical study regarding women, feminism and broadcast, this paper contributes to the understanding of feminist radio practice, and offers suggestions of the possibilities of expanded radio as a model of radical feminist broadcast.

1. INTRODUCTION

Considering radio as a form, producer, and transmitter of popular culture, it is important to question who has access to this cultural space, *who* is being represented, and *how* (Mitchell, 1998). It is widely recognised that women, trans, and gender diverse people have been, and continue to be, underrepresented at all levels of production in radio (Gallagher, 1990). Though they are dominated within the masculine hegemonic discourse of radio and sound arts more widely, it does not mean that their dominated position goes uncontested. Feminist musicologist Susan McClary has theorised on some of the strategies used by women[1] musicians to challenge the 'absurd and pernicious stereotypes that have plagued [them] for centuries' and have systemically excluded them from participating fully (or at all), in music production. (McClary, 1991). Phillipa Stafford and Julia Drouhin are two such artists who have developed a practice that implements strategies of contestation. In this paper, their 'expanded radio' practice is investigated as a reimagining of the broadcast medium. In this reimagining, radio becomes a cultural space which cultivates communities of active listeners and sound makers, generates networks of shared knowledge and technical skills, and begins to build inclusive systems that operate as a *feminine economy.*

2. SISTERS AKOUSMATICA

Sisters Akousmatica is the collaborative duo of Tasmanian based sound artists Julia Drouhin and Phillipa Stafford. According to their curatorial statement (which reads as a manifesto of sorts), *Sisters Akousmatica*'s practice develops 'curatorial, artistic and written projects which are concerned with collective radio practices, auditory-spatial exploration' (Sisters Akousmatica, 2019a).

The project was launched in 2016 as part of Next Wave festival's Emerging Curators program, developed in association with Australian sound arts organisation Liquid Architecture (Next Wave, 2016). Their debut was a large-scale transmission event involving live sound performance, radio broadcast and audience participation in a 'city scale radio-orchestra' (Sisters Akousmatica, 2019c). Over seven hours, seven women artists performed live on the banks of the Yarra River in Melbourne, their sounds being broadcast live via radio transmission. At the same time, Drouhin and Stafford led an audience of listeners armed with portable radios around the city, stopping at various locations to tune into each live performance (Sisters Akousmatica, 2019c).

From this debut as a stand-alone project, 'Sisters Akousmatica' has developed into an umbrella for Drouhin and Stafford's collective arts practice, which intersects the forms of installation, live broadcast, live improvised electronic sound, written research, curation, workshops and retreat for women, trans and gender diverse artists (Sisters Akousmatica, 2019a).

One of their recent works, *Cutting Laps,* was a custom-built wandering radio station in the form of a transmitter built into the body of a car. This car transmitter was driven around the streets of Castlemaine nightly as part of the Castlemaine State Festival, broadcasting works

[1] Here, and at various points throughout this paper, the term 'women' is used to refer to all those excluded by the masculine hegemony, including cis-female, trans, non-binary and gender diverse people. This is not intended to minimise the visibility of trans and gender diverse folks.

by international artists Verónica Mota, Celeste Oram, Anna Raimondo, and Beatriz Ferreyra. The broadcast could be listened to using any radio device within a 1km radius of the 'brum brum radio car' (Sisters Akousmatica, 2019f).

Another example of their work is an installation for moon rising signals, titled *RISING,* which was selected as a finalist work for the Women's Art Prize Tasmania 2019 and presented as a touring exhibition across three galleries in Tasmania. The installation was constructed using a radio transmitter and receiver, audio player, speakers, mineral, brass and paper (Sisters Akousmatica, 2019d). Using these two projects as a small sample of their work across three years, it is obvious that *Sisters Akousmatica'*s practice is extremely diverse.

Despite this diversity, their creative output is collected under the one banner, self-described as belonging to the 'expanded radio' medium, unified by an interest in 'the potential of emergent art forms to support, promote and cultivate socio-cultural and gender minorities in the field of sound arts' (Sisters Akousmatica, 2019a). With such variation in the creative outcomes of this medium, what exactly might a definition of 'expanded radio' entail? Using *Sisters Akousmatica*'s practice as an example, the medium (as its name suggests) seems less concerned with creating definitive boundaries for itself to exist within, and more concerned with the ever-expanding radical possibilities of radio removed from institutional power structures and traditions. So, rather than attempting to define 'expanded radio' and its boundaries as a medium, the author proposes expanded radio as a model of *radical feminist broadcast.* Using a feminist theoretical framework informed by musicologist Susan McClary and theorists Hélène Cixous and Luce Irigaray, this discussion investigates how the 'expanded radio' practice of *Sisters Akousmatica* may allow women and gender diverse people to reimagine the cultural space of radio.

3. RADICAL FEMINIST BROADCAST

At this point it may be useful to briefly elaborate on the proposed term 'radical feminist broadcast' as a blanket term to describe experimental broadcast or transmission art concerned with contesting the masculine dominated discourse of radio.

A general paucity in the area of feminist radio study means there is limited terminology, and what little of it does exist is far from universal. Caroline Mitchell proposes women's community radio as a potential 'feminist public sphere', and uses temporary community broadcast projects as case studies to investigate models of 'feminist radio praxis' (Mitchell, 1998). Mitchell's suggestion of 'feminist radio praxis' is a term applicable to *Sisters Akousmatica'*s practice, but falls short in communicating the radicalisation of traditional broadcast structures. The use of '*praxis*', referring to 'the practical side of a profession or field of study, as opposed to the theory' (Collins, 2019), also excludes the theoretical and academic aspects of *Sisters Akousmatica'*s practice. On the other hand, Austrian National Radio program *Kunstradio* have attempted to define 'radio art' as 'not a combination of radio and art. Radio art is radio by artists', (Kunstradio, 2019). This term 'radio art' (at face value, and according to *Kunstradio*'s definition) sufficiently communicates the possibilities of engaging with radio in non-traditional ways, but fails to express the social and cultural implications of a project such as *Sisters Akousmatica.*

As an alternative to the terminology above, the author proposes the term 'radical feminist broadcast' as a blanket term applicable to experimental broadcast projects concerned with promoting feminist values, and contesting the masculine dominated cultural space of radio. The word 'radical' is operating in a number of ways. Firstly, it refers to a radicalisation of radio tradition, in its sonic content. Secondly, a radicalisation of the gendered practice & discourse promulgated by the institutional power structures of commercial radio. Thirdly, it is important to understand 'radical' as 'concerned with … fundamental aspects of a matter' (Collins, 2019). The term 'radical feminist broadcast' attempts to signify these things concurrently. In regards to the research of *Sisters Akousmatica* specifically, this term seems most indicative of the sonic aspects of, as well as the social and cultural intentions and implications of, their practice.

4. EXPANDED RADIO AS A FEMININE ECONOMY

Feminist theorist Luce Irigaray argues that in modern society the feminine is the cathectical *other* of masculine, phallocentric desire and discourse (Irigaray, 1985). Indeterminate, the feminine is constantly attempting to redefine itself outside of a masculine discourse (Mitchell, 1999). This assertion allows us to (re)consider how the feminine may be recovered, reconstructed, redefined, re-presented through alternative, non-phallocentric discourses, termed *ecriture feminine* by Hélène Cixous. Her essay *The Laugh of the Medusa* presents the 'feminine economy' as an example of *ecriture feminine,* and as opposed to a masculine economy, which operates on a fear of loss (of accumulated capital), a feminine economy operates on a logic of giving without expectation of receiving in return:

> *She gives more, with no assurance that she'll get back even some unexpected profit from what she puts out … This is an 'economy' that can no longer be put in economic terms. Wherever she loves, all the old concepts of management are left behind.*
>
> (Cixous, 1976)

Cixous' concept of the feminine economy as based on the freely given gift presents alternative means for exercising knowledge, given without predetermined bounds or stipulation of how that knowledge may be used (Mitchell, 1999). Radio is innately a gift (in Cixous' understanding of the term); sound, voice and knowledge given to an undetermined audience at no cost, with no expectation of

receiving anything from that audience in return. But commercial and institutional radio stations still operate under a masculine economy. As an alternative, *Sisters Akousmatica*'s 'expanded radio' permits us to reimagine the economic and cultural power structures of radio by using the freely given gift and the feminine economy.

As part of *Sisters Akousmatica'*s project *Cutting Laps,* transmitter building workshops with children from Candlebark Primary School can be observed as an example of the freely given gift. Here, the practical skills and technical knowledge of radio transmitter building is being given freely to the children. *Cutting Laps* also involved a student talk on curating resistances as a peripheral event, as well as a community call out to enter the *Cutting Laps* car and produce a one minute sound work to be broadcast live (from amongst the backseat pillows, rainbow-fur paneling, and beaded chandelier trims):

> *#cutttinglaps started!!! … You can come in the Brum Brum radio car and make your own 1 minute live show!!!* (Sisters Akousmatica, 2019f)

In this instance, the car itself is given as a gift: providing the space and technical equipment needed to create and broadcast your own one minute segment, offered at no cost (Sisters Akousmatica, 2019f). Importantly, there are no stipulations regulating what the segment must sound like, or who has access to the space and opportunity.

In a project such as *Cutting Laps,* we can observe 'expanded radio' as a reimagining of the broadcast medium which grows communities of active listeners and sound makers, generates networks of shared knowledge and technical skills, and begins to build inclusive systems that operate as a feminine economy. As both process and outcome of the growth of these systems, the development of alternative discourses allow women to redefine the *feminine.*

5. ALTERNATIVE DISCOURSES: 'A LANGUAGE TO GET INSIDE OF'

> *If woman has always functioned "within" the discourse of man … it is time for her to dislocate this "within," to explode it, turn it around, and seize it; to make it hers, containing it, taking it in her own mouth, biting that tongue with her very own teeth to invent for herself a language to get inside of.*
> (Cixous, 1976)

The feminine economic sphere generated through *Sisters Akousmatica'*s expanded radio practice provides a space for the dominated to pursue subversive acts and challenge the hegemonic discourse that excludes them (Mitchell, 1998). Alternative media academics (Bredin, 1991; Steiner, 1992), and feminist musicologist Susan McClary have investigated and theorised upon some of the ways women have contested a masculine discourse by creating new forms of practice where feminist values are central to the production and content of what is being produced (Mitchell, 1998). Womens' community radio has been cited as one such form of alternative practice, allowing new discourses to emerge (Jallov, 1992). Furthering this suggestion, the author proposes *Sisters Akousmatica*'s 'expanded radio' as another possible site for this to happen.[2]

From within the feminine economic sphere generated by *Sisters Akousmatica*'s practice, sound makers and listeners alike are enabled to pursue alternative discourses, to 'invent for [themselves] a language to get inside of' (Cixous, 1976). In the text based material that surrounds the project *Sisters Akousmatica,* Drouhin and Stafford utilise language that in itself conjures a radical reimagining of the magical space that radio occupies. Their curatorial statement acts as an example of this, its poeticism holding uncanny resemblance to Cixous' 1976 essay *The Laugh of the Medusa.* The similarities come down to near exact phrases: Drouhin and Stafford 'are seeking the truth of **herstory**[3]' while Cixous is calling to '[draw] her story into history'. A shared sense of occult wonder, and collective magic permeates both texts:

> *They sing loud with the wind, feet in the ground of sand and ears in the ocean of air: they are radio.*
> (Sisters Akousmatica, 2019a)

> *In women's speech, as in their writing, that element which never stops resonating … that element is the song: first music from the first voice of love which is alive in every woman …* (Cixous, 1976)

Despite being primarily sonic artists, Drouhin and Stafford actively acknowledge the kinship between language and sound, between writing and speaking. Through writing they have created a language to 'get inside of,' generating a discursive model alternative to the masculine discourse of radio.

6. CONCLUSION

This paper investigates the 'expanded radio' medium, and how it may function as a cultural site that allows disenfranchised groups to reimagine the cultural space of radio through alternative discourses. The collaborative broadcast project *Sisters Akousmatica* grows communities of active listeners and sound makers, generates networks of shared knowledge and technical skills, and begins to build inclusive systems that operate on a logic of the freely given gift. From within this feminine economic sphere, sound makers and listeners are provided with a space to pursue alternative discourses,

[2] The author intends to collect qualitative data through interviewing *Sisters Akousmatica* collaborators Phillipa Stafford and Julia Drouhin in order to extend this research as an Honours dissertation

[3] By 'herstory,' Julia and Phillipa mean alternative histories (of gender minorities) that have often been excluded from the supposedly "objective" and "neutral" written histories of Western sound arts (McClary, 1991).

and subvert the masculine hegemonic discourse that excludes them. More research into radical feminist broadcast deserves attention, especially in the context of Australia; a country whose vastness has necessitated radio as an important social and cultural tool in building community and developing a sense of collective identity. This investigation presents 'expanded radio' as an exciting medium that may enable women, trans, non-binary and gender diverse people to radically reimagine the cultural space of radio.

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PRACTICING CREATIVITY AND THE PEDAGOGICAL BENEFITS OF "BEAT CYPHERS"

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ABSTRACT

This paper demonstrates the pedagogical and creative practice benefit of "beat cyphers". Borrowing from online music community and particularly hip-hop culture practices, beat cyphers challenge participants with varied restrictions and short development time frames for composition/production projects. By focusing upon rapid development of a large body of shorter pieces, it is argued that artists achieve greater growth in their creative development than focusing upon select pieces of greater investment. Also adapted as an elective class at Box Hill Institute, this paper examines the pedagogical method and benefits of applying the beat cypher practice to academic curriculum.

1. INTRODUCTION

A "beat cypher" is a regular song-writing and production challenge in which participants must rapidly develop pieces to specific briefs. Often the restrictions include the use of certain samples or a particular tempo. It's important that the cyphers are completed quickly and frequently, or at least attempted on a regular schedule. A huge focus of the task is making regular output (often weekly, fortnightly or monthly). Submissions to a cypher are collected and exhibited through some online presence, perhaps as a playlist or sometimes as a longer interwoven DJ style mix.

2. THE CULTURAL LANGUAGE OF BEAT CYPHERS

Beat cyphers are musically diverse now, but to understand the underlying ethos we need to briefly explore their roots in hip-hop and city bred American "street" culture. In this space, much that is still deemed laudable is also considered ephemeral. Street art for example is transient, if you don't own the wall it was painted on you understand the work may be gone tomorrow.

There's also the idea of hard work, prolific output and slowly building recognition coded into the many verses of rap lyrics. Whilst operating far from a strict conservatory honed system, eager lyricists in this space still understand the value of repeated exercise. This training earns a possible ego boosting public showing in rap "cyphers", in which unwritten "freestyle" verses are spontaneously performed on the spot in various gatherings. Good freestylers are held in high regard as masters as of their craft, and there is no doubt about the amount of practice it takes to build that skill.

But what of the musicians and producers who make the foundation for hip-hop music? How can they similarly grind out a volume of work to refine their skills? Spontaneous in-person output is a much more demanding task for their medium, but the idea of a repeated exercise and opportunity to boast one's skills publicly still exists in the "beat cypher" practice. Like many cultural shifts of the last few decades, the internet plays a huge part in facilitating the network and stage for which the work can be seen and shared.

I also want to draw attention to the word "beat" itself. Hip- hop is of course very rhythm focused music, but it is language again coded with an understanding of transience. A "work" or a "piece" is language intended to imply something grander, with weight and worthy of lengthy inspection. A "beat" is a tool, it is not without some reverence, but it is more utilitarian. When working with MCs, producers often need to possess a large library of possible "beats" (i.e. instrumental tracks) to find something the rapper will take inspiration from. Again, there is a value placed on quantity, so you better make a lot of beats to have a lot of tools in your tool-belt.

It's not about a binary choice between quantity and quality, but rather an enthused quest for finding the latter through the former. Not to sweat out a magnum opus on rare occasion, but to build a talent by making something of even a modicum of worth as often as you can.

This is the esteemed R&B and neo-soul singer Erykah Badu on working with the equally revered and especially prolific Hip-hop producer J Dilla in 1998:

> *They* [Dilla and fellow producer Madlib] *are so serious about what they are doing to the point where they make beats all day long. That's what they do. All. Day. Long. Don't even save them, just put it right to a CD. They give out these CDs, volume one, two, three, four, five, volume 121. And when you pick a track, they don't know where the sample came from...*
>
> (Red Bull Music Academy 2011)

3. STRENGTH IN NUMBERS

My own introduction to beat cyphers came first from a mini documentary produced by the music software company Ableton, titled "Team Supreme: Strength in Numbers" (Ableton 2016). This video profiles a group of producers from Los Angeles who had been creating regular cypher mix tapes since 2012 (a "mix tape" in this context refers to a blended overlapping mix between a series of songs, like a recording of a DJ performance). The video charts the rise of this project from a humble collaborative endeavour between friends to a widely recognised and much sought-after placement opportunity as an online open submission monthly compilation. This group have now become quite the poster children of the concept, thanks both to their prolific output and the signal boost of this documentary. The title of the video is deliberately championing the ethos of a then blossoming modern online music community movement. One artist is easily lost in a crowd, but a community that grows together can support one another.

In another interview, producer and Team Supreme member JNTHN STEIN offered this on the value of artist collectives:

> *Collectives in the blooming electronic music scene are a way to bypass the compartmentalization and elitism of the established record industry. You have the power to achieve on a large scale... growing community beyond even your actual collective.*
>
> (Splice 2017)

Soon after the release of this documentary I began to see its impact on Melbourne's community of budding electronic music artists. Beat Cyphers became a topic of discussion often at The Ableton User Group Melbourne (Ableton User Group Melbourne 2019), a monthly enthusiast meet-up event co-organised by myself and fellow Ableton Certified Trainer Matt Ridgway. Soon a local community called "Beat Collective" (Beat Collective 2019) formed to begin their own regular cypher series on a fortnightly basis. The cyphers adhered to one of the most common restrictions, you must use the two new samples provided with each iteration. I began to participate as often as I was able.

4. PRACTICING CREATIVITY

I discovered a freedom in making songs for this cypher that I never really had in other projects. For one I was unshackled from the business-end needs of my output, such as worrying about which song was the single or would it suit this or that pseudonym. There also seemed to be much less of an emphasis placed upon making something of grand value. It was simply enough to exercise a small creative idea and see an outcome, in the form of a release format and opportunity for feedback from my peers. I felt that it was safe to experiment, to try new ideas that may fail or explore different repertoire. I learned a lot and developed a lot as a composer and producer in a comparatively short space of time to the prior speed of my song-writing output.

When instrumentalists practice scales and standards they seek to make information immediate and ingrained, to build muscle memory and instant recall. It helps build a foundation, after absorbing the basic mechanics a player can reach for new conceptual ideas.

It is one thing to practice a rote or physical skill, it is another thing to practice having original ideas of merit (which is academic and author Ken Robinson's Ph.D. definition of creativity that I choose to adopt). What does it mean to practice creativity? What is the equivalent of musician's scales, the repeatable exercises for that? I have found that beat cyphers are a fantastic answer for this problem. This is especially assistive for relatively new artists making some of their earliest work, such as the students I encounter. Hence, after participating in the practice for a while I took on the task of adapting it as a subject for Box Hill Institute.

5. THE BEAT CYPHER CLASS FRAMEWORK

To contextualize the next aspects of discussion, I will briefly outline the core components of the class I now run. Each week students receive a new song-writing brief of varying restrictions. These vary in difficulty and focus, and include examples like using certain samples, a certain production technique (e.g. automate on parameter on every plugin/device) or compositional element (e.g. forced use of counter melody, hocket or a key change). A consistent restriction is the time limit; each song must be 1:30-2:30 in length. The students work on their tracks outside of the class time, effectively as homework. Class time is reserved for playing back the tracks on the speakers, and occasionally through other formats (such as paired speed dating sessions, swapping headphones). After listening to each track, the students are led through feedback activities where they comment upon one another's work as class discussions. This format repeats each week, and by the end of the 12-week semester they have made 11 songs.

It is surprising to watch the students who are not eager participants in other classrooms devote hours of time outside of class each week to this task. I have had the least academic of students describe to me that this was the one class that never felt like "work". The large volume of time required rarely seems to be considered an issue.

6. THE NEEDS OF BEAT CYPHER'S LEARNERS

To elaborate on what kind of needs in my students the beat cypher class addresses, I want to provide some information about the kind of learners I encounter in our programs.

I have encountered a lot of students in my classrooms that have built an impression of themselves as inherently poor by comparison to their peers (at whatever task we

would be covering that day). They would assume that this is inherent to their making and begin a lot of apologies with the words "sorry, I am not...". For example: "sorry, I am not very good at song-writing." In these discussions, there was no hint that this was a reflection of their current state, but rather their final conclusion. They had given no thought to the comparative length of time each student in the room may have spent at the task. There is a much longer conversation to be had about ego and the standardized school system that may have given birth to these attitudes, but at the point of my intervention the most important task is how to correct them.

I find the attitude of assuming all ability to be predetermined to be pointlessly defeatist. It seems more meritorious to me to consider first and foremost that you get better at something by doing it more often and for longer. It seems obvious to say, but somehow also often forgotten. Particularly when the skill in question is a more abstract mental skill such as idea generation.

Much of the educational model that I have taught within is built on longer ramps of learning to few outcomes. For example: a semesters worth of study of music production techniques that is assembled into one song project and one exam. This is not without justification, as there are a lot of technical and mechanical skills students need to demonstrate their understanding of. However, it does not aid in supporting the approach of "you get better at something by doing it more often and for longer". Students still need to complete the loop of starting, developing and finishing creative projects as many times as they can to refine these skills into tools for their own creative endeavours.

A trait I often observe in the slightly more self-assured students is that they make music on their own time, but rarely finish anything. It is easy for them to start a new project and be spurred on by the exciting potential it holds, but much harder to see this through to a final outcome. Eventually a mental disconnect widens between their early hopes and goals for the project vs. how it actually manifested. Disheartened by this separation or simply frustrated at the difficulty, the project becomes abandoned. When I ask my students in week one of beat cypher if their hard drive contains a bounty of work that never got finished, I receive a chorus of positive replies. For some, this is all they have accumulated, never having entirely finished a single song. The issue here is in part that they have practiced extensively, but exclusively on starting songs. They have put in very few hours practicing finishing songs and hence are simply poorer at that skill. It's hard to get past the hurdle of feeling like you are squandering the earlier efforts, but you need to be bad at something for a while before you can improve. They need a construct like the beat cypher class to force this task upon them.

Completed or not, another issue I have observed is that students spend a really long time with each song project. Again, this can have a lot to do with expectations, and what kind of pedestal of creative hopes is being built under each piece. Students are often unable to see the length of the road ahead, pinning a lot of their desires for realizing their artistic voice into each new project. I ask them to consider how they think their approach would be different if they were writing not their fifth song, but their five hundredth. Many of us with a larger catalogue of work will know that we look back upon our earlier pieces with some mixed emotions. Time has earned us clarity on the flaws we were unable to see then, but without having made the work we would not have gathered those lessons. I hope that by giving students a framework to turn out this work more quickly, they too will have those learning experiences without spending so long in anguish.

At other times even the best of us simply hit a creative paralysis, or "writers block". This is a terrifying issue in its first few occurrences for a young student. Especially if working to the gospel of trying to create as much output as possible. By having a new brief each week, students have something to propel themselves off of a blank page. They have a lot of creative freedom, but their options are not entirely limitless. Once they have begun by attacking the needs of the current brief, reportedly they have found that a creative flow state becomes easier to grasp.

Finally, the other common trait I have observed in these students is that they are incredibly hungry for feedback, but unsure of how to get it. There are other mechanisms budding songwriters and producers will turn to, such as sending mp3s between peers or posting in online forums. These come with inherent flaws or biases. Their friends might not always forthcoming with criticism, and it's hard to break through the noise in online social platforms to have any lengthy discussion. Frequently the vocabulary and eloquence of those addressing their work is limited, and misinterpretation becomes rife. Our beat cypher class is an avenue to get feedback each week with my guidance. I provide prompts, aid students where they struggle to find the right words, keep the feedback balanced and constructive. We have conversations in class about constructive criticism itself, and the students develop this skill too.

I have seen a lot of poor written work from music and production students. I think language can be undervalued as a tool for understanding other conceptual aims and options. Beat Cypher is in part a stealth language class. We talk about the aural concepts that are difficult to define, find terms for their observations and figure out how to structure their feedback effectively. I keep a glossary activity accessible on our online subject page for valuable language that comes up in our discussions. When grading the written work of students in later years, it is easy to see those who studied beat cypher and those who did not. With a classroom of eloquent peers, they become better communicators and everyone receives better feedback.

7. TRANSLATING CULTURAL PRACTICE TO ACADEMIC STRUCTURE

I recognise that there are core principles of "beat cyphers" that are not new ideas, but by adopting this cultural language I have found myself as a teacher able to reach a new audience. There is in particular a class of contemporary "song-writers' who would never really self- identify under that label. The modern moniker for these students is "producer", which is importantly an updated definition from the era of Quincy Jones. The modern producer is associated with the varying branches of electronic music, from hip-hop to dance although the label continues to widen still. Most importantly they are often self-sufficient, armed with a laptop, pirated software and YouTube tutorials as their means of gathering scattered information. They have largely arrived at the pursuit of a music career without an instrumentalist's musical background. This has burdened them with a degree of imposter syndrome, and whilst they feel alien in a "song- writing" classroom they still yearn for that information and personal growth.

Academic structures in music are slowly shifting to account for the change in the industry to a multi-disciplinarian focus. Where we previously segregated the performers, writers and engineers we are now learning to see these as skills needed by almost every learner. However, that doesn't mean that every learner will absorb the required material by the same means, and I think the cultural baggage still plays a big part in this. Even by titling the class "Beat Cypher", enthusiasts of contemporary genres are telegraphed that they are safe to exhibit their music that's often considered otherwise low brow in academic settings.

There are still some difficulties in adopting the beat cypher practice to a classroom. For one, standardised testing brings the burden of not being able to assess students on their own growth but rather against set expectations. Additionally, to be fair to the students the classroom actually spends more time teaching language then it does on specific techniques like how to write a melody or balance a mix. Hence the testing needs to significantly reflect what information the classroom has given them, so we include peer and self-review written assessments amongst the briefs themselves. However, there are advantages to using an academic structure too, as suddenly a failure to keep up the weekly practice comes with consequence (in poor assessment results). I find some students after the holidays yearning for that structure again, as they were unable to keep up the habit on their own despite their best intentions.

8. CONCLUSIONS

I believe it is really important that whilst studying students have a chance to explore a breadth of work and learn by lots of practice. I have observed my students get better and faster at their output, and rocket ahead in the quality of their work against peers in other programs. They have learned to make their best art by first simply focusing on making the most art. I would encourage any other teacher to find a place in their curriculum for a similar program, separate from those classes where students are learning the fundamental skills at a slower pace. There needs to be a space for students to experiment in turning those skills into creative outcomes as often as possible. I also encourage teachers to use that environment to foster a sense of community. Expose the students to each other's work and engage them in conversation about it. Ideally, they almost shouldn't need us, and could run the entire class of discussing the work and setting new challenges on their own. This is the ethos and self-motivation they need to carry into their creative practice post study.

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THE SPACES BETWEEN GESTURE, SOUND AND IMAGE

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ABSTRACT

Improvised audiovisual performance is becoming an increasingly rich field of creative practice, fuelled by the image-centricity of contemporary performance culture and increasingly affordable and powerful technology for live digital image projection. However, the domains of audio and visual creativity frequently remain separate. Both theoretical discourse and practical training tend to focus on one domain in exclusion to (or at least with significant priority over) the other.

For example, contemporary literature on new interfaces for musical expression are frequently centred on aspects of design and expressivity within the framework of music performance alone, and discussions on interactive and graphic scores for contemporary music performance focus the affordances of the visual score as a medium. Meanwhile there are limited frames of reference for examining improvised audiovisual performance as an integrated practice.

In this analysis, we focus on integrating the concept of gestural surrogacy from the spectromorphological tradition with concepts of multi-sensory feature binding. To support this investigation, we utilise case-studies of three distinct approaches to audiovisual performance practice, using a combination of motiongram and spectrogram analysis along with artistic comment from the authors of each piece.

1. INTRODUCTION

In examining three improvised audiovisual works, we look at the intrinsic aspects of each authors' process in terms of the individual compositional and performative dialectic of intention and result, including sources of inspiration, creative processes and expressivity. These reflections are necessarily subjective and may offer little to others in terms of directly translatable understanding or re-usable process.

To complement this subjective approach, we also examine the morphological qualities of both the audio and visual elements of each performance, in effect looking at the 'trace' of each audiovisual performance.

Visualisations of this kind are not unprecedented in the realm of analysing complex performances: Borgo (2005) uses fractal correlation as a means of examining the features of improvised musical performances by the like of Evan Parker and others, while Jensenius (2010) and Francoise (2012) have developed systems for analysing physical gestures and sound together.

A multi-sensory approach to understanding visual music need not treat the visual trace as reductive. Rather, it can point to an underlying unification of perception within the body. Key to this perspective is evidence for a close coupling between the cognitive processes for movement and perception. Leman (2008, p. 77-102) provides extensive discussion of the evidence, including the behavioural observation of infants' innate ability to perceive gestures and replicate them, and the neurobiological observation that some of the same neurons which are fired to create a gesture also fire when the subject observes another performing the same action. These are the so-called mirror neurons.

The tight coupling of movement and perception at a cognitive level gives rise to the idea that just as our movements arise from intentions (simulation of the movement), so perceptions of the external world map back to intentions because of the trace left by the shared cognitive processes. This action-oriented ontology suggests that even at the social level, the actions of others are understood in terms our own intentions, i.e. our own simulated actions. The ``moving sonic forms'' of music are likewise attributed with intentionality because of the coupling of perception and movement. Arguably, because human beings develop their own action-oriented ontology by virtue of a relatively common physiology, semantic communication is possible through music, even without a common culture (Leman 2008, p. 92).

By utilising analytical tools which draw directly on the qualities of both sound and motion, our goal is to support a discussion of the intersubjectivity of abstraction and embodiment that manifests in visual music, particularly looking at the idea of gestural surrogacy. While there are many other frameworks for analysing movement and visual aesthetics, for visual music it seems most appropriate to draw upon the existing analytical

tradition of acousmatic music, particularly Dennis Smalley's work on spectromorphology (Smalley 1986, 1997). Smalley's typology is laden with physical metaphors and is sufficiently general so as to be applicable to human movement, and by extension, qualities of visual perception in general, as much as it is to spectrally moving forms in the auditory domain.

At the root level, Smalley considers sound in terms of motions, space, structural functions and behaviours. Motions include both the motion of sounding objects, including such categories as ascent, descent, oscillation, rotation, dilation, contraction, convergence, and divergence. He also suggests several characteristic motions including floating, drifting, rising, flowing, pushing or dragging. One can easily imagine these categories being applied to human movement, at either the individual or group level, and by extension the visual morphologies of audiovisual artworks.

When we consider the gestural relationship between sound and vision in visual music, it is useful to look at the way in which Smalley links spectromophological forms of sound art to the morphology of human movement (Smalley 1997), an insight which is backed by the work of Leman. The key idea here is that we make sense of what we see and hear by drawing upon our experience as embodied beings, even though in visual music the experience to which we attend is generally abstracted away from anything immediately recognisable. From a compositional perspective, Smalley identifies several levels of *gestural surrogacy*, in terms of degrees of abstraction away from both the source material the gestural archetype:

- primal gesture: basic proprioceptive gestural awareness, not linked to music making
- first order: recognisable audiovisual material subject to recognisable gestural *play* without *instrumentalisation*
- second order: traditional instrumental musical performance
- third order: where a gesture is inferred or imagined in the music, but both the source material and the specific gesture are uncertain.
- remote: where ``*source and cause become unknown and unknowable as any human action behind the sound disappears*'', but ... ``*some vestiges of gesture might still remain*'', *revealed by ``those characteristics of effort and resistance perceived in the trajectory of gesture*''.

Building on an awareness of the primal gestural level, first order surrogacy provides simple, immediate accessibility for the interactor, while sustained engagement is generated by providing elements which operate at the higher levels of gestural surrogacy. The aesthesic process is further complicated by the fact that the relationship between audibly perceptible gestures and visually perceptible gestures is not necessarily direct, but exists on a spectrum. In addition, such gestures may not follow the normal rules of physics in the material world (and in the context of an art work, it would probably be quite boring if they did).

A simple example of such gestural mapping is that of ventriloquism: the puppet's mouth movements are linked with audible speech events and although we know that puppet's don't speak, perceptually we are still convinced that the sound is coming from its mouth. Despite the novelty of the effect, the congruence of audiovisual stimuli result in what O'Callahan (2017, p. 162) argues for as perceptual feature-binding: a multi-sensory perception of the same event which may have distinct features such red and rough or bright and loud, but are nonetheless a unified percept. In Smalley's terms, the ventriloquist's performance would contain elements of first order gestural surrogacy.

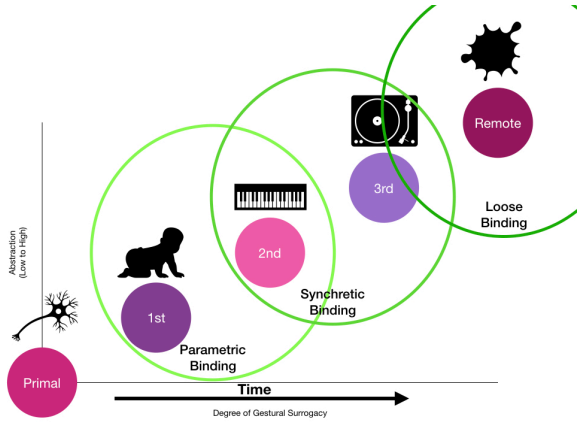

Figure 1. Gestural surrogacy and perceptual feature binding.

Figure 1 shows a mapping between Smalley's concepts of gestural surrogacy, and concepts of perceptual feature binding. Lower-order gestural surrogacy may manifest in visual music through direct parametric mapping between sound and visual elements. For example, the amplitude of a percussive sound being directly linked to the size of a visual element such that repeated patterns of an underlying gesture may result in an experience of auditory and visual pulsing. In this way, the size of the visual object and the amplitude of the sonic object may be perceived to be the result of the same gesture of `striking', even though in our experience of the material world, while percussive instruments may in fact make a louder noise the harder we hit them, visual objects do not routinely become bigger when we hit them.

The same approach could be taken to linking sound elements which may have a floating or gliding quality with, for example, visual elements that also have the same quality of movement. Such a relationship may be parametric, as might be observed via visualisation of audio as a waveform, where a gently undulating tone may have a similar quality to its shape. Or the relationship may be formed through synchresis, that is, simply if two elements appear within the relevant perceptual stream at

the same time, without having any explicit parametric mapping at a compositional level.

It can be difficult to distinguish between parametric mapping and synchresis, as the mapping is typically hidden and only inferred (we imagine the ventriloquist is controlling the puppet, but we typically don't see it explicitly, we only see the puppet's movements synchronising with audio events). This is the paradoxical challenge of a well-realised mapping process: when the mapping is seamless, the audience assumption can be that events in one sense modality have just been composed to synchronise with events in the other, rather than having one arise from the other. Live performance can help reduce this effect by demonstrating that multi-sensory events are arising from a common gestural source in the moment, rather than being pre-composed.

Which brings us to the point that it is important to distinguish between the degree of unification within an audiovisual event (tight versus loose feature-binding) and the degree of gestural surrogacy. If we consider gesture, whether it be in performance or on-screen or auditory, to be a recognisable pattern of experience, then gestures can be thought of as arising from the features of an event as it unfolds. Certainly tightly bound features, recognisable elements within an event, which consistently co-occur or share the same qualities, may be perceived as being the result of first or second order gestures. Such an inference arises because of embodied cognition: our experience of physical movement informs our experience of surrogate forms of movement in other `bodies'.

Loosely bound features bring uncertainty into the experience of an event: is there a common gesture, a common cause? Are these phenomena even linked? Within such uncertainty, it is harder to recognise the gesture behind them, however that does not mean it is not there. At higher degrees of gestural surrogacy, we may experience less overt, conscious recognition, receiving only hints or vestiges of an underlying pattern. The original gesture may be disrupted or distorted in some way, through interruption, amalgamation or elongation, and yet still evoke a response.

To draw together the various threads of this background discussion, we suggest that within visual music, the spectrum of multi-sensory gestural associations arise from, and abstract our own embodied cognitive processes, and that through examining both the creative intent of the composer/performer and the various gestural traces, however we might obtain them, a deeper understanding emerges. Within this framework of understanding, we present reflections on three audiovisual performances. These are examined as an engagement with the intersection of multiple perceptual modes which operate as a space for collaborative art-making beyond the confines of textuality and symbolic representation. Our hope is that as a result, the reader is inspired to engage more deeply in their own experience of the form.

2. WIND SOUND BREATH

Wind Sound Breath is a visual music[1] work by Brigid Burke, performed in this instance by Nunique Quartet (Brigid Burke, Steve Falk, Megan Kenny and Charles MacInnes). This piece utilises densely layered and heavily processed visual material incorporating elements of video footage and graphic elements. In this piece, the visual material is fixed and performances are largely improvised, with certain recognisable elements used to mark sections of the performance.

The piece incorporates live and pre-recorded interactive audio electronics, live visual footage and synchronized video for live performance. Thematically, the piece draws inspiration from Yarra Bend Park, the natural bush land near Melbourne Polytechnic. Wind-Sound-Breath explores connections with the present histories within the campus, Burke's own musical influences and the importance of the Yarra Bend as an ecological site. In the performance analysed here, live instruments included clarinet, percussion, flute, trombone, and live electronics. An overview is given in Figure 2.

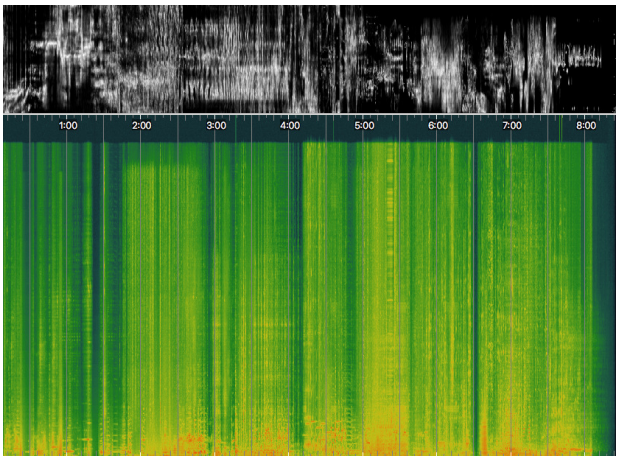

Figure 2. *Wind Sound Breath* Overview

Figure 3 shows detail of an excerpt between 1:46 and 2:17. Sparse clarinet and flute notes enter in the first 10 seconds, distributed against a background of field recordings of ocean waves and a wood fire. Visually, dense root-like patterns fade in and out with slow pulses of colour, modulated by a rippling visual overlay. The motiongram shows the periodic pulsing of this segment and spectrogram show a number of loose correlations between the visual pulse and bands of broadband noise, in this case arising from modulations of the volume of the ocean and wood fire recordings.

[1] In this context, visual music is considered to be a work in which both audio material and on-screen visual material are integrated elements of the total work, allowing for one or both modalities to be improvised or fixed.

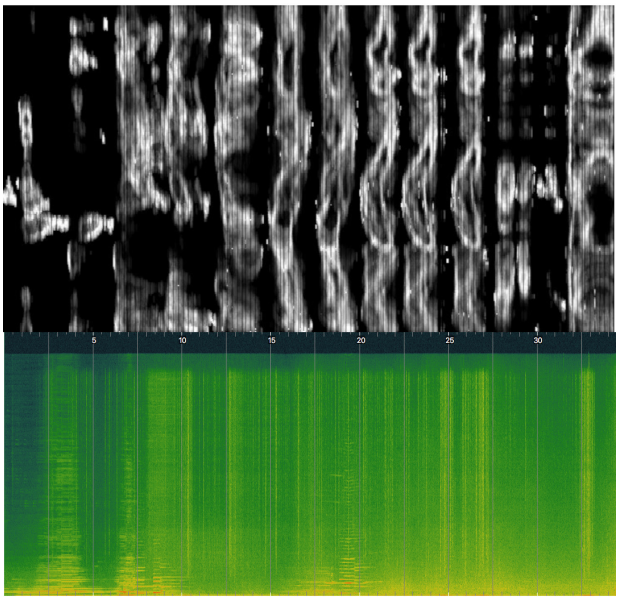

Figure 3. *Wind Sound Breath* excerpt 1.

Figure 4 shows detail of an excerpt between 3:50 and 4:10. This much more active section features lively figures of trombone, clarinet and flute over timpani, with elements of reversed tape material. Visually the underlying root-like pattern persists, layered with footage of monochromatic lapping water and highly colourized, horizontally scrolling footage of a cityscape. Approximately halfway through the excerpt, the colourized city footage begins to shrink behind the monochromatic water footage. A corresponding drop in activity in the motiongram can be seen from this point. Likewise, activity in the audio performance drops away, with less volume and density compared to the first half.

From Burke's perspective as the composer, the aesthetic focus of the work is on exploring relationships between composition, improvisation, visual impact and listening. While pre-composed visual elements are utilised, these are used in improvised video projection performance alongside the improvised audio performance. Audio performers are free to interpret the visual score as it unfolds, and the visual material itself is modified as part of the performance.

In speaking about her process, Brigid Burke explains that concepts for a piece often start with a visual structure in mind, which then drives her to seek out sounds which match that internal visualisation. In terms of actual material, sound always comes first, after which visual elements are created or collected to fit with the audio material. This kind of round trip between an internally visualised concept, sonically realised and followed by a visual realisation, keeps the various elements tightly bound. Burke notes that she's found if she starts with creating visual material first, the piece tends to lack coherence compared to pieces which have audio as the material foundation.

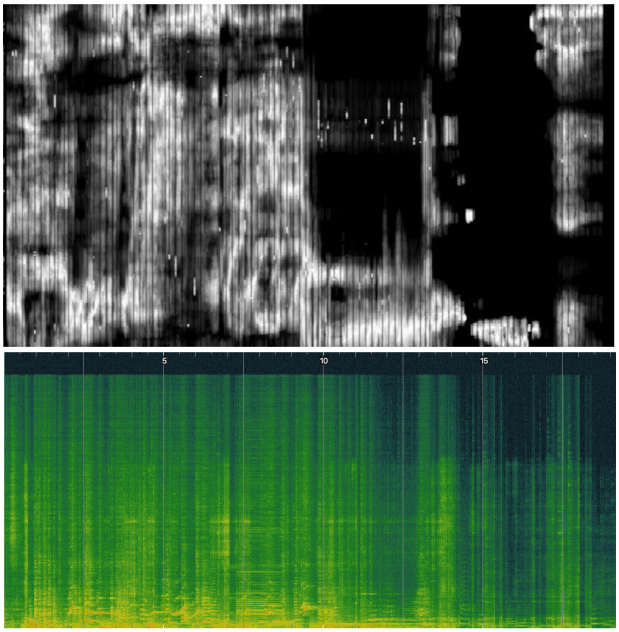

Figure 4. *Wind Sound Breath* excerpt 2.

For live performance, Burke is frequently manipulating one or more elements of either the audio or visual material in addition to live instrumental performance. Live clarinet performance is combined with either live video mixing or live manipulation of synthetic audio elements.

In ensemble performances, the visual element acts in terms of setting the dynamics of instrumental improvisation. This can be seen in the analysis above, with various dynamic changes synchronising across both audio and visual elements. However, the relationship is not just one way, from visual score to audio performance. For Burke, the relationship with other players in the ensemble are of equal weight in terms of shaping the dynamics of her playing and manipulation of either video or audio elements. Thus, while not directly parametric, there is a degree of feedback between audio performance and visual performance which binds the work into a multi-sensory whole.

3. SHIVER AND SPINE

Roger Alsop's piece *Shiver and Spine*, for solo guitar and responsive visuals, demonstrates another approach to audiovisual improvisation: one in which visual material arises from the sonic performance, as opposed to improvisations which respond to fixed visual media. A dynamic visual element, depicting the apparent victor of recent internal political struggles within the Australian Federal Government, leaps on the screen in response to distorted gestures from an electric guitar. Figure 5 shows a still from the performance, while Figure 6 provides an analytical overview of the work.

Figure 5. *Shiver and Spine* still.

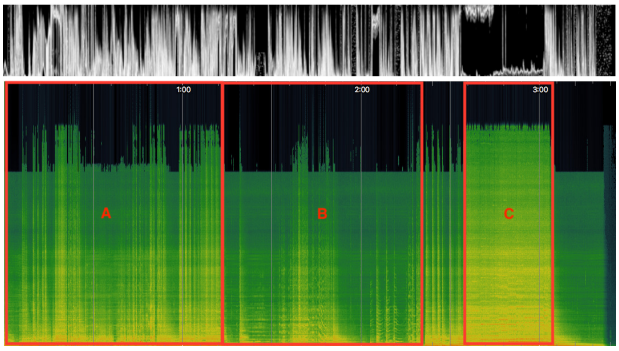

Figure 6. Analysis of *Shiver and Spine*.

In the overview, three episodes are marked. Episode A (from 0 to 1:12), introduces the elements of the piece, with video elements distorting in terms of shape, luminance and colour in response to distorted chords and textural scratching from the guitar. During this section, audio and video appear to be tightly synchronised. Episode B (from 1:12 to 2:25) is comparatively sparse, with occasional struck chords left to decay before more gentle tapping of strings is used to re-introduce movement. Video elements continue to be active during the decay of each chord, calling into question exactly what drives the motion - is it frequency modulation rather than attack, or is there a less direct relationship than had previously been suggested by the performance during episode A?

A short section of stronger struck chords introduces episode C (from 2:35 to 3:05), which shows a distinct drop in visual activity in the motiongram with a corresponding sustained block of broadband audio activity in the spectrogram, generated by fierce strumming by Alsop. The responsive visual material is literally saturated by this block of audio input, filling the screen with a red field of colour - an extreme close up of the piece's subject.

It is conceivable that without the image of the performer and the guitar in the room, there would be no way to determine if the audio or the visual elements were dominant. In fact, only through a tacit understanding of the technical processes, coupled with the tightly synchronous performance, would the audience be able to determine that the visuals are responding to the audio and not that the performer is responding to the visuals. Like Burke's *Wind Sound Breath*, *Shiver and Spine* does set up a feedback loop between the responsive visuals and the audio performer: at a gestural level, visual response invites audio exploration, and perhaps at the broader discursive level, the sheer repetition of the subject's image, pushes the audio performer into a moment of sonic rage such as we see in episode C.

Alsop frequently creates works which utilise audio-responsive visual elements and does so in a way which enfolds the performer and the audience within a recursive loop of stimulus and response. He observes that many interactive audiovisual artworks function to augment human performance, and in this way work as an instrument rather than an interlocutor. In many of his works, rather than create work that unifies or coheres disparate elements, Alsop seeks to interpret human gesture of performance as a different artwork, to be viewed without and separate from the human element involved in its creation. In this regard, he considers it important that when interacting with systems for audiovisual improvisation, performers experience their own actions are represented in an unfamiliar way, so that they do not revert to familiar styles or clichés similar to those they may use when interacting with another performers (dancers, musicians).

4. APOPHENIC TRANSMISSION

Apophenic Transmission (i) is part of a series of live performance works which interrogates the human tendency to spontaneously perceive connections and meaning in unrelated phenomena. In this work the performer is challenged to seek occasions of apophenia through the use of a somewhat opaque and chaotic control interface, in much the same way as one might attempt to tune a radio or a television set to a dead channel for the purpose of encountering electronic voice phenomena. Both the audio and the visual elements are purely generative, with the audio arising from a software simulation of the Synthi AKS, and the visuals arising from software simulation of an analog video synthesier.

Part of the purpose of this piece is to call into question the parametric mapping approach to visual music, which Pedersen frequently uses. While the physical performance controls used for both the generative audio and video elements overlap, the performance framework for *Apophenic Transmission (i)* deliberately confuses this control interface, so that both performer and audience have cause to question whether there is any direct relationship between what is heard and what is seen. As Garro (2012) suggests. ``*visual music is more than a mapping exercise; the absence of a relationship is itself a relationship*".

Figure 7 gives the spectrogram and motiongram analysis for the whole piece. Compared to the audiovisual analysis of the preceding works, it is no surprise that observable correspondences between sound and vision are hard to extract.

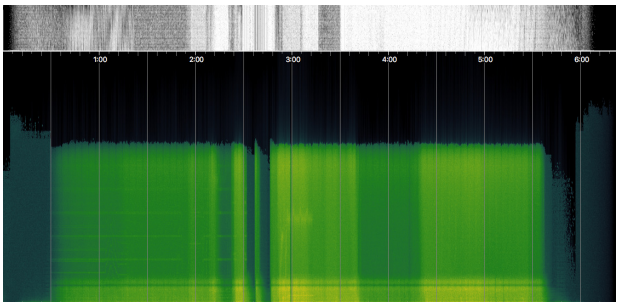

Figure 7. *Apophenic Transmission (i)* overview.

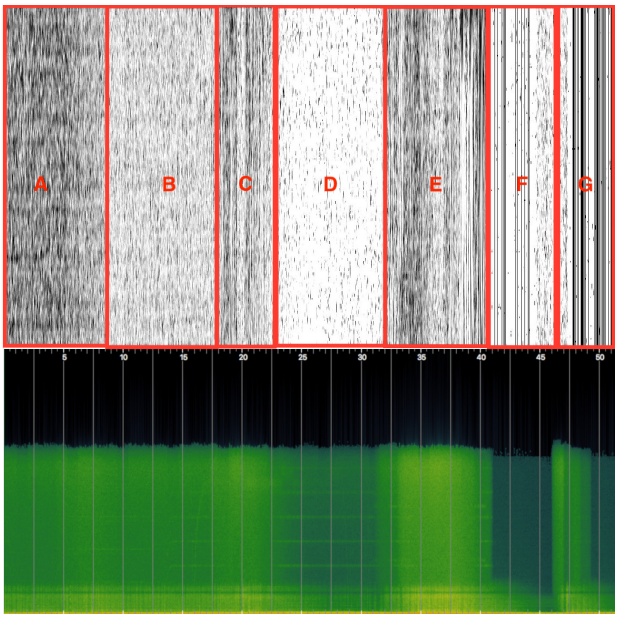

Figure 8. *Apophenic Transmission (i)* excerpt 1.

Looking more closely at an excerpt from between 1:51 and 2:42, shown in Figure 8, we can start to identify features which may trace a common underlying gesture. The motiongram shows several distinct episodes, labelled A - G. In the spectrogram we can see corresponding changes in each of these episodes, although some are more subtle than others.

Comparing screenshots from episodes B and D, as shown in Figures 9 and 10, there is a shift from visual static to a more structured pattern. In episode D, the width of the visual bands pulse dynamically. There is broadband noise in episode B, which drops away in episode D to reveal beating sine tones, which can be seen as horizontal bands across the spectrogram. These same bands are also faintly apparent in the spectrogram of episode B, but the broadband noise masks them. Episode E exhibits the same qualities as B, and episode F exhibits the same qualities as episode D. Thus, the piece starts to establish a gestural link between the presence of audio and visual noise, which masks other underlying patterns.

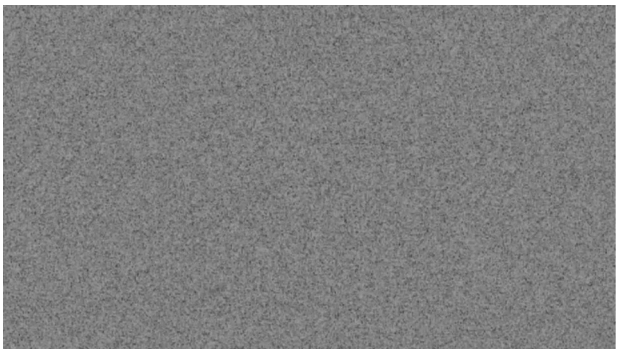

Figure 9. *Apophenic Transmission (i)* still 1.

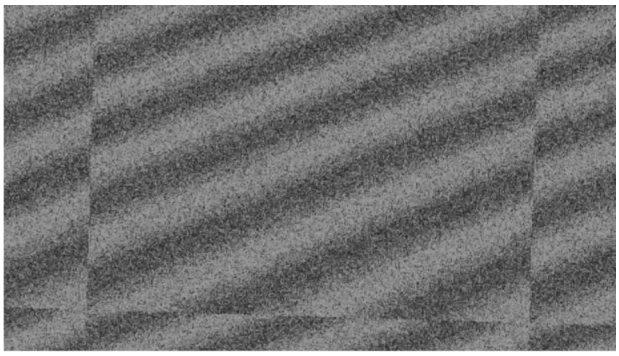

Figure 10. *Apophenic Transmission (i)* still 2.

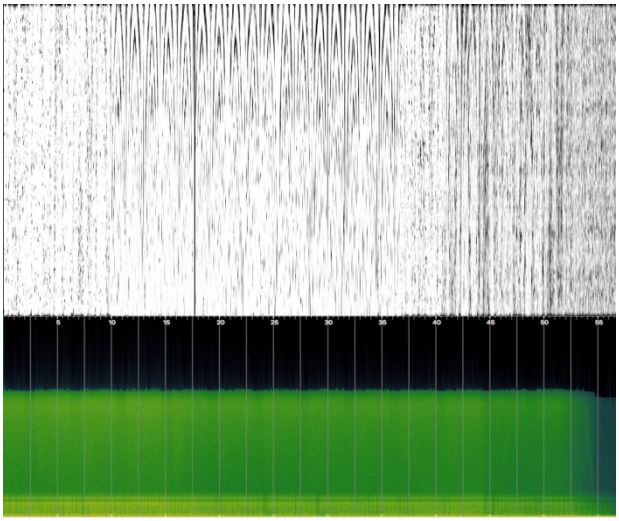

Figure 21. *Apophenic Transmission (i)* excerpt 2.

Figure 11 shows a segment close to the end of piece. High frequency noise still sits across this section, but it decreases in energy across the episode, becoming weaker and lower in frequency between 50 seconds and the end of the clip. Visually we can observe a distinct oscillating pattern across the top of the motiongram between 10-40 secs, which corresponds to a pattern of horizontal bands expanding and contracting in a general downward rolling bounce, typical of the classic bouncing ball motion of modulated low frequency oscillator. The audio spectrogram shows periodic punctuations in the high frequency noise band, which correspond to the lowest point of the visual oscillation (when the horizontal bands are at their widest). The strength of this pattern gradually

declines from 35 seconds onward, with lower contrast visually, and a corresponding reduction in high frequency noise content.

Pedersen notes that for him, performances start *"in the body"*. His internal feeling is the generative core of each performance, and physical expression of that emotion is typically an essential component. His aim is seeking sounds, or rather transformations of sounds, which match the expressive quality of that internal feeling. In this sense, sound becomes the vehicle for expressing the internal (emotional) state. The range of expression could be very dynamic or very subtle, and the interfaces which support the appropriate range of gestures are a key consideration.

In this regard, a performative aspect to each piece is important, and correlations between gesture and sonic effect are highly desirable. For dynamic pieces, interfaces which allow a range of performative gestures, such as Kinect motion sensors, are preferred. Subtle performances are more easily accommodated via traditional knob and slider interfaces. Each system may still need to be learned in terms of gesture mapping. Difficulty in performance is ok, and often welcomed, as the challenge of various gestures can be part of the desired emotional expression. Likewise, it is sometimes important to not know or understand the mapping. In this case the feeling being sought is one of loss of control / confusion.

This is the case for *Apophenic Transmission (i)*, where the control surface used for performance is mapped into both the audio and visual generation systems, which otherwise are independent from each other. The mapping is deliberately unstable and unrehearsed - leading to accidental, or unintentional correspondences as the performer seeks to understand the affordances of the control surface, both visual and auditory, just as the audience is also seeking to make sense of the system.

5. CONCLUSION

In considering visual music, particularly where there is an element of improvisation, the body is a natural starting point for sense making, since as embodied beings, sound cognition is intimately linked with the way our brains also process movement. Yet as habitual meaning makers, bare experience is not sufficient: there is a human tendency to ascribe intent to what we perceive as gestures, however abstract, and connect those gestures with our own personal history and framework for understanding the world.

When visual music, as a genre, actively resists narrative, which may be considered the realm of cinema, then what remains is affect - the mood or the feeling, that which is present before narrative emerges, or perhaps that which remains after narrative has been taken away. Furthermore, we are specifically interested in the nexus of audiovisual performance as a field of affect, as distinct from that which may arise from just a single channel auditory or visual experience. Rutherford (2003) suggests that *"shape, colour, texture, protrusions and flourishes all reach out and draw us to them in an affective resonance"*, particularly highlighting the work of Michael Taussig on mimesis, quoting:

> *"It is not the mind's eye that reaches out to grasp or grope the image or space before me—it is my embodied self locating, placing myself in the world which I am viewing."* Taussig (2018)

With this in mind, and drawing upon O'Callaghan's (2017) argument that perception is truly multi-sensory, it is perhaps useful to consider visual music as being an integrated space of *"affective resonance"*. Within this mimetic space, it is the quality of the gestures embodied within audiovisual art works, however abstracted they may be, which evoke engagement with the audience.

Considering the examples analysed here, what affective resonances arise?

In *Wind Sound Breath* there is perhaps a sense of playfulness in the performance as a whole as it shifts between delicate, interlocking filigrees and occasions of robust wrestling. *Shiver and Spine* is comparatively much more raw, possibly evoking anger or at least frustration in the urgent, distorted guitar, as both performer and audience alike are taunted by a kind of jack-in-the-box visual element. In contrast, *Apophenic Transmission (i)* evokes a degree of confusion, a tentative, exploratory questioning or doubt about what is being seen and heard. With little that is overt in terms of gesture, the experience is more akin to a half-remembered dream, for both performer and audience.

In reflecting on our experience with hosting audiovisual improvisation events for more than six years, the experience of liveness that arises from the sharing of gestures in the moment is the compelling reason to continue participating, for creators, performers and audience members alike. If, as Taussig suggests, the act of perception is itself also a gesture, then we are all seeking those moments of contact that arise beyond (or beneath) narrative, in the space between gesture, sound and image.

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‘WANT IT TO END’: TOWARDS A VIRTUAL THEATRE ENVIRONMENT

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ABSTRACT

This research and artistic work illustrates some preliminary steps taken towards creating ‘virtual theatre environments’.[1] These works are motivated by the desire to give participants an embodied, first-person experience of a specific mental state. A creative work is produced, entitled ‘Want it to End’, in which participants are led through a live performance space wearing Virtual Reality (VR) headsets. The subject material focuses on experiences of anxiety. This paper gives an overview of the approach used to create the work. A brief survey of VR and Immersive Theatre literature is used to contextualise the creative work. Using the ‘Want it to End’ example, the paper addresses aspects of the planning to realisation process of creating a virtual theatre. These aspects include ‘Metacognitive scripting’, 360-degree filming, audio composition, spatialisation and performance. In addition, curated interoceptive and exteroceptive stimulation techniques for performance are considered. Conclusions are discussed with regard to their implications for current and future project developments.

1. INTRODUCTION

1.1. Origins and Overview of Virtual Reality (VR)

French avant-garde playwright, poet and theorist Antonin Artaud asserted that illusion was not distinct from reality, advocating that spectators at a play should suspend disbelief and regard the drama on stage as reality. He is credited with the first use of the term *Virtual Reality* (Artaud & Richards, 1958).

The ‘Sensorama’, shown in Figure 1, was a machine patented in 1962 by inventor Morton Heilig. It was designed as a giant box and looked almost like a racing car simulator crossed with a photo booth (Patent No. US3050870A, 1962).

Figure 1 The “Sensorama” (Source: Engadget.com).

In 1981, French sociologist Jean Baudrillard declared that information devours its own content and that we live in a hyper-reality where we cannot distinguish reality from a simulation of reality.

Char Davie’s ground-breaking immersive virtual reality installation *Osmose* saw participants (or ‘*immersants’*, as Davies calls them) wear a Head-Mounted Display (HMD) and a body suit which monitored their breathing and balance. Depending on the rate of breathing or motion, one could find themselves embedded within a clearing, cloud or forest. Breathe too deeply and you were immersed in philosophical quotes about the clouds. Too shallow and you would find yours below the surface, observing the source code of the program (Davies, 1995).

1.2. Defining VR

Virtual Reality is not a homogenous concept. As individuals and as a society, we consume so much media that it is easy to put forward an argument that we are already engaged with copious volumes of virtual reality – through news media, video games, novels, podcasts, etc. Or that, in fact, we already live in a Virtual Reality – least a virtually *mediated* reality.

1 An intermedia theatre work, that is immersive in nature, and incorporates the use of Virtual Reality (VR) within a continuous performance.

Worthy of philosophical interrogation as this is, it does not really assist us in defining our research area and what we want to achieve through the medium termed 'Virtual Reality' or what we mean by a 'Virtual Theatre'.

Sherman & Craig (2019, p. 6-15) give five key elements essential to a Virtual Reality Experience:

1. *Participants*
2. *Creators*
3. *Virtual World*
4. *Immersion*
5. *Interactivity*

Many key elements are not solely relevant to VR. However, by outlining these parameters, Sherman & Craig reveal a unique bundle of characteristics which help to define what a VR experience is. For the purposes of this paper, we have sought to utilise Sherman & Craig's five key elements. Importantly, these elements were satisfied in the context of a virtual theatre production which utilised VR headsets.

1.3. Origins and overview of Immersive Theatre

Immersive theatre is generally regarded as theatre which breaks with notions of a fourth wall[2]. This theatre is generally not presented in an auditorium with regular seating and a stage. Often these performances invite audience participation and/or offer agency to the audience as to how they interact with the performance. This removes them from the role of spectator and repositions them as a participant.

Mandell (2016, p. 11) attempts to define clear cut attributes to the term *Immersive Theatre* asserting that, for a work to be worthy of the term, it needs to include the following:

1. A multi-sensory approach (taste, touch and smell, augmenting sight and sound);
2. A sense that the show is as much art installation as theater piece;
3. Personalization of the experience (where experiences of the audience vary, not just in interpretation of the material but in objective experience);
4. An emphasis on the social via "playful interaction";
5. The centrality of a story, no matter how fractured or obscure.

Public performance and notions of interactive performance is nothing new. Anything from Medieval theatre up to current-day street performances, could be said to satisfy the requirements of current buzz terms such as "Immersive", "Participatory" or "Site-Specific".

Nonetheless, Mandell's attributes of what constitutes an immersive theatre performance are helpful to us, if we are to work towards a broader definition of a 'Virtual Theatre'.

1.4. What is a 'Virtual Theatre'?

Defining a Virtual Theatre is difficult, and it should be noted that we are only attempting to define what it means in the context of the creation of our own artworks. We are not talking about a Virtual Theatre as a simulation for a medical operation. Nor are we talking about theatre delivered by VR, as in the theatre piece 'Staging Second Life' (Russell Fewster, Denise Wood, & Joff Chafer, 2011). This research is focused on developing a framework for creating intermedia[3] work that integrates VR with the theatre to create an unbroken, narrative-driven performance. By combining Sherman & Craig's key VR elements with Mandell's immersive theatre attributes, we can define a Virtual Theatre as:

An intermedia theatre work, that is immersive in nature, and incorporates the use of Virtual Reality within a continuous performance.

2. PLANNING FOR A VIRTUAL THEATRE EXPERIENCE

2.1. Consideration of the participant and the philosophical underpinnings of virtual theatre modality

Bay-Cheng, Kattenbelt, Lavender, & Nelson, (2010) are concerned with modes of experience within Intermedia work. They discuss five different modes of experience, which we have summarised here:

1. *Experiencer* -
   An experiencer's interaction with the performers and the technology/media creates the artistic work.

2. *Embodiment* -
   As it exists across interactions with all technology and media present in a work.

3. *Intimacy* -
   A sharing, or combination, of perceptual frames between experiencer and performer.

4. *Presence* -
   Given the nature of intermedia work, presence extends beyond spatiotemporal locality. In intermedia work, presence is negotiated using the transitional spaces between the live and the digital.

5. *Immersion* -

2 The imaginary boundary between audience and performer, generally demarcated by a stage for performers and seating for an audience.

3 Various inter-disciplinary art activities that occur between genres and disciplines (Higgins, 2001)

> The sensory experience/perception of being submerged (being present) in an electronically mediated environment. Virtual theatre can extend this to an overlap between different realities.

Bay-Cheng, Kattenbelt, Lavender, & Nelson's work can appear to be quite abstract and obtuse. As such, it is difficult to ascertain practical application for a virtual theatre context. However, the distillation of experiences into a perceptual map that the authors provide is useful in deciding what to focus on within a virtual theatre context.

2.2. Metacognitive Scripting

2.2.1. An overview

Metacognition is broadly defined as 'knowing about knowing' or 'thinking about thinking' (Flavell, 1979; Livingston, 2003; Metcalfe & Shimamura, 1994). Flavell (1979) proposed metacognition as consisting of metacognitive knowledge and metacognitive experiences. He divides this into knowledge of person variables (what we know about how we learn), task variables (what we know about the nature of a task and the processing demands it has on us) and strategy variables (what we know about strategies that we can apply to successfully accomplish a task).

It is naturally common for artists to consider the audience in the creation of any work. Indeed, the artist-audience relationship is a very large field of study in its own right (Bloom & Erlandson, 2003; Durgnat, 1970; Trivedi, 2004). It is also discussed widely in popular discourse, for instance in relation to getting a larger subscriber base on one's online media channels. However, this type of discussion is generally around the efficacy of the artist's message. When we talk about 'metacognitive scripting' we are scripting the creative material from the internal viewpoint of a participant. We are simultaneously evaluating the efficacy of our artistic message and scripting elements of their objective experience in a multisensorial manner.

2.2.2. Metacognitive scripting in the 'Want it to End' experience

The 'Want it to End' mixed reality experience started out with the following logline:

> *"Participants perform the role of a protagonist with recurring and debilitating anxiety. The world contorts and burns around them, yet they can't feel anything as a response to the situation. They experience conflicting desires of wanting it to all come to an end, whilst insisting that they stay anxious. They are haunted by their past actions as they are pointedly reminded by a strange colonial-style figure who haunts them throughout a dystopian and surreal Australian rural landscape."*

Rather than set out and script a narrative-driven story based on this logline, we scripted a set of events that we thought best conveyed the scenario. From here, we created a table which included all the staging and setting elements.

We viewed each action within the scenes as an action of the mind, rather than action within the content. We designed the instances of experience within the work with the idea that a participant may interpret them as actions, thoughts or memories. Scripting from this point allowed us to explore feelings participants might experience, and the narratives which they build around those feelings in their mind. Each 'sense-event' we created would need to facilitate the building of this internal narrative within the participant.

2.3. Filming VR content for a virtual theatre experience

2.3.1. Considering Experiencer, Embodiment, Intimacy, Presence and Immersion

Each scene was scripted from the point of view (POV) of the experiencer. The ultimate immersion of the 360-degree environment within the theatrical performance space had to be central to the planning of the filmed component. If the experiencer was to be the protagonist within our story, we had to define the characteristics of their embodiment, intimacy and presence before they were there.

Starting with the sequence of events from *Figure 2* allowed us to explore what would be going on phenomenologically and in terms of the five key modes of Experiencer, Embodiment, Intimacy, Presence and Immersion. For instance, in the campfire scene, what are possible interpretations of their surrounds is the participant having at this time? Is the participant feeling cold? Are their thoughts clear or clouded? As a result, are the sounds they hear diegetic or seemingly supernatural? Do they feel the dirt beneath them, or do they feel something else beneath them because they are visiting this space as a dream?

It was important for us to pose these questions in order to maintain an appropriate level of ambiguity. In keeping with the goal of leaving it experiential and open to interpretation, the result was a simultaneously physical and realistic world, layered over with visuals and sounds that were evocative of the supernatural. By considering each event as simultaneously a thought, memory and action, we had embedded our participants in a beautiful yet paradoxical world that made no sense except for the fact that you were undeniably inside this reality in a spatiotemporal sense. As one participant reported:

> *"I just became used to [the world] and accepted that*

skies were purple and contained fish, whilst a bushranger in a hat was giving me plastic water bottles full of strange elixirs and dogs barked in harmony with each other."

Figure 2 shows some visuals from the *Want it to End* experience. The image is a 3D image presented in 2D for the sake of publication. It features clouds and rural bushland layers.

Figure 2 Still from Desert scene of "Want it to End".

2.3.2. Creating effective Point-Of-View for enhanced embodiment

One consistent trouble in filming in 360 at the time of writing is getting a clear first person, 'embodied' experience. One often looks down in an experience to see either a black blotch (caused by rig-removal), a tripod, or simply nothing at all. Either this, or one finds themselves moving on a body but can see the head of the person that they are traveling on. Many sequences in the *Want it to End* experience required a body. They are listed here with their relevant solution:

Driving a car:

Headless mannequin with suit jacket covering the body placed in driver's seat. Custom camera attachment with a scarf wrapped around the base of the camera. Holes placed in the suit jacket. One of the authors hid themselves behind the driver's seat and placed their hands through the suit jacket and on the steering wheel. The car was then driven at a slow pace.

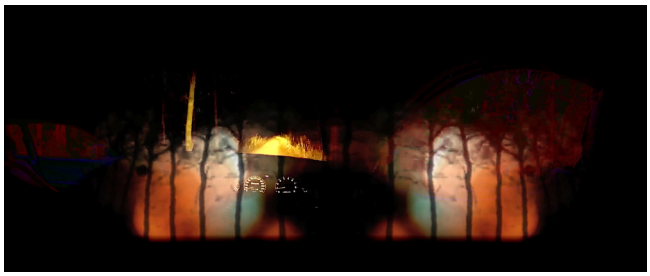

Figure 3 Night time driving scene, with flashing layers to represent potential memories of a car accident.

Walking:

One author wore the custom camera attachment with a scarf at the base. Height became a consideration in this instance and the wearer had to lower themselves so that they did not appear too tall.

Figure 4 Walking scene. Filmed in Linton Victoria.

Figure 5 Same scene as *Figure 4,* as it was experienced in the theatrical context. Performance at Aeso Studio, May 2018.

During the theatrical experience, participants were walked through a series of "sense-events" that made the kinaesthetic reality match the virtual reality they were watching in the HMDs. Figure 4 shows the vision from the HMD perspective. Figure 5 shows the theatrical performance. Curated smell sensations are occurring whilst the participants are led barefoot over grass.

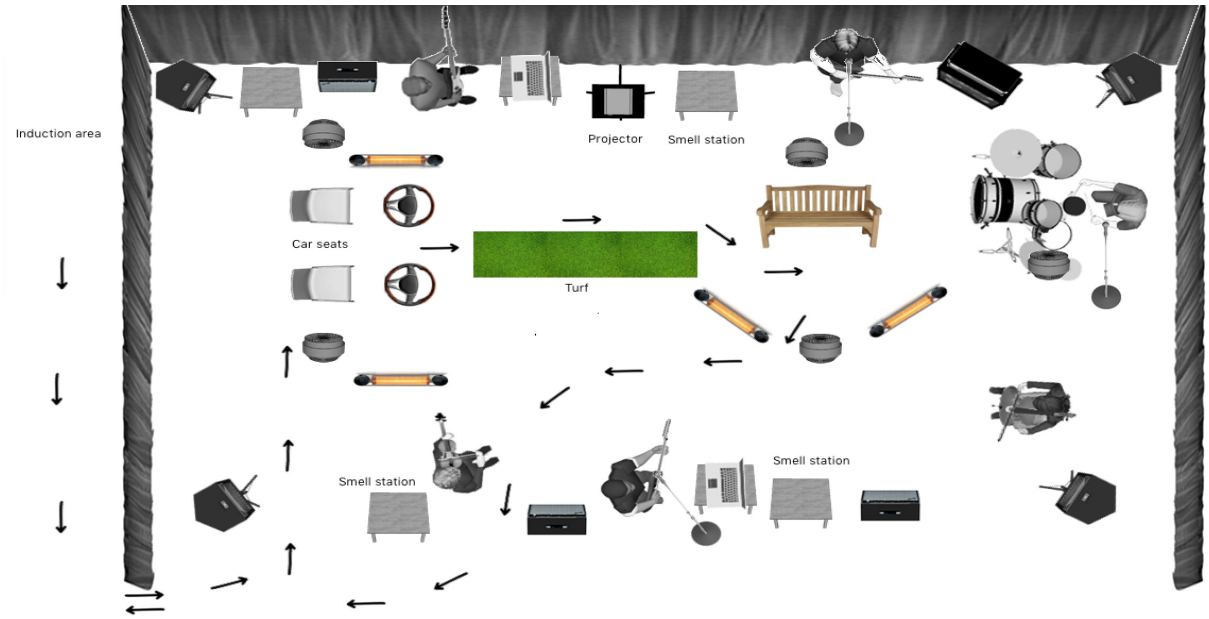

Figure 6 "Want it to End" stage plot. Includes interoceptive and exteroceptive tools, performers, technology, direction of audience flow, relevant props.

2.4. Audio and composition for a virtual theatre environment

2.4.1. Considering Experiencer, Embodiment, Intimacy, Presence and Immersion

In a virtual theatre context, involving the use of HMDs for the period of time that the participant is within the headset, the participant exists in a different visual reality to the performers. As composers, sound designers and performers, we can start by considering ourselves as something of a 'universe-jumper'. Performers of the music are physically co-present to participants who are mentally with the performance. As such, musicians are 'performing on' their audiences, rather than 'performing to' them.

2.4.2. *Diegetic levels of sound within a virtual theatre experience*

According to Gorbman (1976), sound source on the narrative level may be diegetic[4], extra-diegetic[5], and meta-diegetic[6]. Meta-diegetic is sound imagined, or perhaps, hallucinated by a character. In the 'Want it to End' experienced, we started with the premise that all sounds made in the space could represent any level of diegesis. Given our premise that all stimuli could be interpreted as thoughts, memories or actions, it seemed logical to imagine that all three were at play within the musical composition. Diegetic sounds that corresponded with the visual sounds (e.g. walking) were played and embedded into the music. Meta-diegetic sounds were to correspond with much of our metacognitive scripting. For instance, if the participant was scripted to feel intense anxiety at a specific point, dissonant strings could be used. In terms of the extra-diegetic, we utilised Fierce Mild's song 'Lost Highway', which was also performed live. This song was broken up with additional scoring and performance. We acknowledge that – being that participants were characters themselves – they obviously heard this music. However, its function was very similar to the extra-diegetic sound of a film as gave cues to the participants as to how to feel about the imagery.

2.4.3. Spatialisation

Complex sound fields have been integral to 'immersive' art environments since at least the 1920s (Wendel, 2012). So too is it integral to a virtual theatre space. The ultimate goal would be something of a high order ambisonic speaker array combined with different elevated positions and spatialisation of all instrumental players and singers. However, in the 'Want it to End' experience we were limited to forty square meters of space. Within this space, at one time, we had 5 musical performers with all of their equipment, 2 guides and 2 participants who roamed the space. With a quadraphonic PA set up, spaced out amplifiers and a large drum kit, performance and timbre became key to best immersing the participant in the sound world.

2.4.4. Instrumentation and timbre selection

The 'Want it to End' experiences contained the following instrumentation:

Fierce Mild ensemble

- Voice
- Electric guitar (prepared and unprepared)

4 Sound experienced by the characters
5 Sound not experience by the character, but heard by the audience

- Bass guitar
- Cello
- Violin
- Drums

Additional Instrumentation

- Percussion – Djembe, seedpod shaker, Tambourine processed through effects
- Jaw-Harp
- Hapi Drum
- Samples, Ableton effects, Sound Toys, Altiverb, Valhalla, Occulus Spatialiser, Envelop for Live

2.5. Performing audio in 'Want it to End'

As musical performers we were 'performing to' our audience within a singular location. However, two subjective realities existed. Each interaction is innately different. One begins to sense the disposition and relative levels of comfort of participants. Some were petrified, whilst others were open to anything that came their way. The seriousness of 'performing' was less as the audience could not view us. This gave us scope for clearly communicating with each other about a sound event (such as a gong sound behind the participant's head) without giving anything away about what we were planning.

Sometimes we would whisper in the participant's ears or breathe slightly on their neck. Given the aesthetic merging of electronic soundscapes with rock, it became pivotal to know when to move from the channel strip[7] to direct interaction with a participant. A scream would first appear within amplified, quadrophonic sound, then it would fade, only to back right behind the participants ear. The sound transitioned from a distanced full-bodied performance, to an intimate encirclement within the space of 10-30 seconds.

2.6. Curating sensation to create embodiment

By definition, our virtual theatre has to be multi-sensory in nature. We are interested here in exploring the ability of sensory stimulation within performance to create a deeper sense of embodied experience which could perhaps cultivate societal empathy towards neuro-diverse people – such as those experiencing anxiety disorders. We can do this by examining the results of stimulating different aspects of the somatosensory[8] system throughout a virtual theatre performance.

Klich (2019) refers to a 'visceral dramaturgy' in her practice-as-research project *Daphne in three Movements*. She argues that employing a visceral dramaturgy can facilitate a heightened awareness of one's own proprioception[9], viscerception[10], and sense of active being and functioning in the world. It is unclear whether her work solely focuses on the viscera or whether this a term used to describe an approach to theatre that attempts to elicit more interoceptive[11] awareness in the audience. However, it is a useful term when describing a type of theatre which seeks to direct an audience's attention towards their inner mental and emotional states.

Indeed, much art has been concerned with the viscera and interoceptive responses. Chaim Soutine painted images of dead rabbits and slabs of beef in thick oil paintings. When viewing these, one may feel or imagine the sensation of particular viscera stretching and contorting. Seth (2019), using the prism of Expressionist art, argues that visual experience is shaped by interoceptive predictions, and in turn emotional responses. Therefore, whether consciously or not, it is integral to any art-making process.

Figure 7 Chaim Soutine's *Fish, Pepper Onions* (c. 1919)

2.6.1. A theatre of multiple senses – the Want it to End example

The 'Want it to End' experience made use of the following senses: smell, taste, thermoception (heating and cooling; wind direction), hygroreception (detection of moisture content) somatosensory (touch), proprioception and misattribution.

Verbal testimonies from participants during informal conversations after the experience have led us to suspect that these senses created a much deeper sense of embodiment to the experience, and a deeper sense of engagement with the work, than if they had not been included. Further, more empirical, research would be required to state this conclusively.

2.7. Scoring for a multisensory composition

In terms of a score, musicians followed a cue-sheet which was made using the same video but with sense and emotion event cues.

7 Meaning to move from performing with amplified sound through a mic to acoustically projecting the sound into the space
8 The system in the human body, of sensory neurons and pathways, that responds to changes at the surface or inside the body
9 Sense of body position and movement
10 Senses arising from stimulation of the viscera (internal organs)
11 The sense of the internal state of the body

3. TECHNICAL CONSIDERATIONS

At the time of research, VR is still considered an emerging medium and there are many 'bugs' associated with working in this environment – particularly works that involve HMDs. Seemingly simple operations can quickly turn into logistical nightmares when a technology is young and without a 'black box' model.[12]

This section gives a basic overview of some of the challenges faced and discusses some resolutions. Whilst this research will do it's best to explain the technical issues at play, it is written from the perspective of an artist and not a technology expert.

3.1. Streaming VR content to multiple devices

Multicasting to headsets presents significant challenges with current technologies. In researching this area, we found many 'turn-key solutions'[13] on offer from private companies and individuals who closely guarded their information to limit competition and safeguard profits. Given resource constraints, we had to embark on the creation of our own set of solutions to the technological issues at play. Based on our findings, we have listed some considerations for integrating VR headsets into a multimedia project of any kind.

3.1.1. Streaming and Syncing files

A basic understanding of computers and networking comes in handy when dealing with a virtual theatre arrangement. Put simply there is a 'server-side', which is controlled by a computer; and a 'client-side' which is the HMD.

For the 'Want it to End' project, we streamed the video content from a Windows laptop, using Skybox VR player to two HMDs (Samsung Gear VR). We first attempted this using a closed network on a TPLink 300mbps router. However, there were issues with port-blocking which meant that the server and client could not detect each other. As such, we chose a work-around that made use of a tethered internet connection from an iPad. This situation was not ideal but did work. Our 'score for the senses' (Section 2.7) was sent over a different signal to its own projector.

3.1.2. File size and quality issues

The current quality of 360-degree filming and playback equipment already poses a challenge. The file sizes are large, and this can create a lot of latency across a network streaming the content. Compressing the files in the 'Want it to End' experience became unfortunately necessary – from approx. 8GB in size, to 1GB.

Part of the bottle neck exists with processing power too. At present, the race is on to develop 'foveated rendering' - a graphics-rendering technique that reduces the processing requirements by greatly reducing the image quality in the peripheral vision within a headset – allowing a processor to focus on where a participant is looking at a given point in time.

3.1.3. Proprietary tools and the need for preloaded content

Some companies offer 'turn-key solutions' to the multiple headset problem. A company called VR SYNC offers monthly licenses at a considerable cost. AV hire companies also rent out this system or similar at high costs.

3.1.4. Developing own interface using Unity 3D

For our future work – *'The Door in Question'* we are developing our own closed system through the software Unity 3D. This will enable us to preload content onto headsets and trigger it from our server-side without having to stream large volumes of data over a network.

3.2. HMDs ability to disrupt the flow of experience in a hybridised virtual theatre

A final but important consideration is the imposing and 'clunky' nature of using a VR headset or HMD. First performed in 2017, Frogman is a production by *Curious Directive* which takes the form of a hybridised virtual theatre. The story centres on a missing girl in Queensland, Australia. The disappearance occurred in the mid 1995. The physical element of the play is set in present day, whilst the VR component is set in 1995. The audience take the role of jurors, who are instructed to put on their headsets at given moments by the actors to 'assess evidence' that is presented through the headset.

Many reviews gave a fairly dim assessment of the play and complained that the narrative was bogged down by gimmickry, for example Woodhead, 2018. The 'Want it to End' experience only had a singular transition moment. However, our future work focuses on exploring continual transitions in a seamless way. As such, scripting for this 'clunkiness' is no doubt an imperative.

Much of what worked for us in *Want it to End* was an abstract and surreal aesthetic which blurred the lines of reality rather than attempting to replicate or simulate it – which much VR does. Though beyond the scope of our discussion here, it may well prove that the medium of VR (in headset form) is more suited to abstract and surreal works. Either way, it is important to consider the character that this new medium can impose on any production and to let the overarching experience determine the ultimate technology necessary to convey the artistic intent.

12 A model whereby the user inputs a command and the computer system produces a result, requiring little to no knowledge on the user's part of how the system works.

13 A type of system built end-to-end for a customer that can be easily implemented into a current business process.

4. REFLECTIONS

4.1. Evaluating the 'Want it to End' experience

The 'Want it to End' experience was initially intended as a way of exploring new frontiers in the way music concerts are presented. As an audio-visual band, Fierce Mild has always considered this a natural evolution. 'Want it to End' was relatively successful. Tickets to the initial, self-produced iteration sold out. The experience was then booked by several local municipalities as part of wider festival umbrellas – West Projections Festival and Melbourne Music Week. This gives us reason to assert that there is a commercial viability in this type of hybridised virtual theatre work; that patrons are indeed very interested in deeper embodiment within their interactions with artistic works.

Through qualitative analysis in the form of participant testimonials, it appeared evident to us that there exists an ability to create deeply embodied via the use of interoceptive and exteroceptive device. Some audience members were so deeply affected by the experience that they requested some time to process what they had experienced before returning to comment on the work to us. It is not possible to say, from our limited testimonials alone, whether or not participants experienced an embodied state of anxiety. Further research that is more empirically motivated is required to assess the efficacy of this type of experience in providing such embodiment.

The terminology around VR is in a state of flux. Many people consider it to be very different things. Indeed, it was difficult to convey through the marketing of the 'Want it to End' experience, exactly what it was. There is often much debate about the success and failures of the technology and whether 'VR is the future' or 'dead in the water'. For us, this debate is frivolous. Artists will utilise whatever tools are around them at a given point in time. Bearing these debates in mind though, it is important to stress that HMDs in the context of the creation of a Virtual Theatre are replaceable with other types of technology. Any reader of this work may feel free to consider the research with any tools in mind that they see fit to use.

4.2. Future work – 'The Door in Question'

'*The door in Question*' is a virtual theatre work exploring an experience of Schizophrenia. Many scenes are created using the writings of the artist's mother, who was diagnosed with schizophrenia. It is also inspired by the artist's lived experience with psychosis.

The creative output focuses on heightened states of paranoia and mental disorganisation. The materials are presented to encourage audiences to gain a sense of understanding to the way that the emotions of love, anger and sadness are expressed within these states. An intermedia work is created which explores methods of utilising exteroceptive and interoceptive techniques as well as visceral dramaturgies in order to give effect to a schizophrenic experience. This work focuses on the faultline between virtuality and physical reality as a worthy point of exploring an 'illness narrative' in a theatrical context. The purpose is to create an artwork utilising lived experience and qualitative research in order to give an engaging representation of the experience that is also truer to life. As such, the research aims to encourage a deeper sense of empathy and understanding towards people who experience schizophrenia and psychosis amongst the community.

This work aims to create several successful transitions between the virtual and physical worlds, exploring the Faultline between the real and the virtual. The techniques developed from the 'Want it to End' experience will be further developed, refined and expanded upon with a similar goal of creating a continuous multi-modal technological based performance which encourages a deeper sense of embodiment.

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TWO PERSPECTIVES ON REBOOTING COMPUTER MUSIC EDUCATION: COMPOSITION AND COMPUTER SCIENCE

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1. ABSTRACT

Laptop ensembles and orchestras, in addition to being hubs for collectives of experimental musicians, have become a popular feature in music technology tertiary education curricula. The (short) history of such groups reveals tensions in what these groups are for, and where they fit within their enfolding institutions. Are the members programmers, composers, or performers? Should laptop ensemble courses focus on performance practice, composition, or digital synthesis? Should they be anarchic or hierarchical? Eschewing potential answers, we instead pose a new question: what happens when computer science students and music students are jumbled together in the same group? In this paper we discuss what a laptop ensemble might have to offer both groups or students and describe the results of our experiments in running joint laptop ensemble courses. We conclude with questions that motivate further iterations of our laptop ensemble as a promising site of computer music education in a modern university environment.

2. INTRODUCTION

This paper provides two perspectives on encouraging the development of an electronic and experimental music scene among university students. The first perspective is one of composition students within a music department, and the second is of "creative coding" students within a computer science department. Computer music has a long history of collaboration and cross-disciplinary development from music and computing faculties. In our efforts to foster engagement with music from both music and computing students we have combined free improvisation performances and open-work compositions from music with laptop ensembles and software engineering processes from computing. These perspectives embrace commonalities while acknowledging the differences between students on both sides of this interdisciplinary field.

In this paper we report on the activities of *LENS*: the *ANU Laptop ENSemble*. We discuss the tensions between both perspectives, and address the impact of new trends in both music and computing education such as a new focus on broad-audience coding education and music production with the academy. Finally, we evaluate the impacts of these perspectives on the students and examine the computer music practices that have emerged so far.

3. BACKGROUND

While computer music ensembles are hardly a new phenomenon (see Bischoff et al. 1978, for an early example), interest in orchestras of laptops surged in the 2000s at universities in the USA including *PlOrk* (Trueman et al. 2006), *SlOrk* (Wang et al. 2009), *L2Ork* (Bukvic et al. 2010), and others. In contrast to electronic music collectives, the "*Ork" model pioneered in Princeton's PlOrk adapted the hierarchical structure of a university orchestra, being composed of a large number of musicians with identical laptop and speaker setups. Wang et al. discussed how this approach tended to emphasise performance practice with computers and was able to attract those who are less experienced with electronic music (Wang et al. 2008).

The laptop ensemble has proven to be a popular format, with Knotts and Collins identifying a history of at least 160 different groups that could be described as such (Knotts and Collins 2014). The technical and organisational settings for these groups varies wildly; some are essentially piano keyboard ensembles (e.g. Cheng 2019) with centralised sound production, while others are more experimental, such as the *Ensemble Feedback Instruments* described by Rosli et al. where performers freely mix and map the inputs and outputs of DIY electronic instruments (Rosli et al. 2015). Some ensembles focus entirely on rehearsals, others a mix of rehearsal and workshop sessions (Trueman et al. 2006), and still others rehearsal and lectures (Bukvic et al. 2010).

When laptop ensembles exist within universities, what exactly are the students learning? Trueman's original argument for PlOrk was to develop a community of practice within the electroacoustic music studio, which was at risk of becoming an individualised practice (Trueman 2007). In one of the few critical evaluations of the laptop orchestra phenomenon from a participant's perspective, Valiquet notes that students of the *Concordia Laptop Orchestra* (*Clork*) value the technical skills gained over the musical outcome which could be seen to exist in a "kind of detached, tolerant aesthetic pluralism" (Valiquet 2018).

Notably, the most high-profile laptop ensembles have existed within the host university's music programs (either

traditional or music tech) rather than computing/computer science programs. Our wish to meet the needs of both computing and music students in a laptop ensemble appears to be somewhat unique.

4. LENS: THE ANU LAPTOP ENSEMBLE

Over the last few years, we three academics—a live-coder and senior lecturer in Computer Science, a percussionist and computer musician and lecturer in Computer Science, and a composer/improviser and lecturer in Music—have been finding ways to bring our students together in meaningful collaborative multimedia projects. Like the LOrk pioneers, we wish to emphasise student-created works rather than existing repertoire. Perhaps unlike them, we are open to different collaborative configurations with subsets of our enrolled students performing works that might include acoustic instruments and live visuals.

Since early 2015 we have run extra-curricular workshops, summer schools, collaborative projects, installations and site-specific performances. Until 2018, all of these projects have almost exclusively involved music students from the Experimental Music Studio. In part due to recent successes in Swift's *Art & Interaction in New Media* CS course (featuring guest lectures from practitioners across the university) there has been a push from the Computer Science side of campus to reach out and provide more creative outlets and opportunities for students.

Given these recent trends, in 2018 we formalised these previously extracurricular activities in the *LENS*: the *ANU Laptop Ensemble*. In the next section we describe how this has been arranged as a for-credit course at the Australian National University (ANU). However, we first wish to discuss the broader reasons *why* we chose to co-run LENS "across the campus" in this way.

4.1 Why run it as a for-credit course at all?

Since 2018 the LENS course has been offered as a for-credit elective for students from either the ANU Research School of Computer Science or the ANU School of Music. This means that students from either CS or music can take the course for credit, and also that the course counts a degree program elective, not a cross-campus elective.

Running the LENS for university credit raises the question: "if the goal is to create a community, is the best approach to give a mark and a grade for participating?" It is important to remember that today's students are under considerable time and economic pressures, which have been shown to cut into the time which once may have been used for extracurricular activities (Beiter et al. 2015). By offering the course for credit, we both free up and incentivise students to create the time and space in their schedules required to participate fully and achieve good results. Additionally, the extrinsic motivation of having assessment can help bring out the best work in (some) students.

There are challenges with this approach: modern universities are large institutions, and attempting to organise enrolments, teaching spaces, and tutors across departments can be challenging. However, we have managed to leverage our existing (good) relationships between the CS and Music schools to make this happen.

4.2 Why should CS students join LENS?

For some students, being asked to make something creative or artistic is what it takes to move them beyond simply "grubbing for grades" to asking questions that make them better computer scientists and software engineers. LENS also provides a context to encourage the dreamers, doodlers and creatives who choose to study CS at university. Too often, students feel that studying CS means giving up their artistic and creative dreams, and CS schools miss out on some brilliant students because of this (see, for example, the literature on STEAM education (Harris and de Bruin 2017)). Running LENS as a CS course is a way of letting these students know that creativity is important and that it's part of doing top-class engineering, CS and design work.

Computing (in the broad sense) is no longer seen in society as an unalloyed (if boring) force for productivity, labour-saving and the general good. New narratives range from techno-utopian visions of post-scarcity to dystopian nightmares of surveillance and oppression. In this context, university CS departments are wrestling with how to teach students to be thoughtful and ethical as well as skilful and effective.

LENS may seem like a strange diversion in light of these much bigger challenges, but creative computing provides an important test-bed for applying computational tools in domains where there is no "right answer" and no objective measure of quality. LENS forces CS students to build something to a specification, but to decide on what "quality and correctness" looks like before attempting to produce it. This is an important skill in the wider context of computers and society, and LENS gives students a taste of these challenges.

4.3 Why should music students join LENS?

Since 2013 the ANU School of Music has been placing an increasing amount of energy and resources behind the development of programs in music technology and composition for film and video games. As these program grow and students complete existing curriculum, a need for additional avenues within the university to stretch their technological capabilities has arisen.

Participating in LENS encourages music students to create their own electronic music tools rather than rely on pre-made loops or plugins. Music students who may or may not already be familiar with synthesisers and electronic music (most often through Ableton Live or other DAWs) learn the fundamentals of synthesis, as well as taking serial techniques and applying them to computerised algorithmic processes. The composition and performance of music without the familiar interfaces of acoustic instruments, standard notation and notation and DAW software give these students a fresh perspective, and a common entry point with their computer science colleagues.

As noted above, the laptop ensemble puts electronic music into a social and collaborative environment. Those who tend towards electronic music composition and production are challenged to find a way for a group to "play" their composition. The question of "who turns which knob, and when?" brings intuitive practice into deliberate composition.

Figure 1. Ben Drury, Charles Martin, Millie Watson, and Ben Harb performing on touchscreen instruments, 2016.

5. LENS COURSE FORMAT

5.1 Version 0: workshops, projects, and collectives

Our earliest experiments with computer music ensembles were related to individual research projects by the authors. Ben Swift's *Viscotheque* system was trialled by ensembles from 2010–2012 (Swift 2013). Charles Martin founded *Ensemble Metatone* in 2013 to explore the combination of percussion and touchscreen music apps (Martin 2017). Alexander Hunter founded the Canberra Experimental Music Studio in 2014 where music and other students were able to participate in free-improvisation and electronic music performances and recordings (e.g., Hunter et al. 2018).

While these projects were fulfilling, the participants performed with either fully-formed musical systems (as in the case of Swift and Martin's groups) or relied heavily on individual participants' independent learning (as in Canberra EMS). Apart from this, the authors were independently teaching large core computer science and music composition subjects, and encountering students who wanted to make computer music but didn't know how. The following attempts to create LENS were designed with those students in mind.

5.2 Version 1: TechLauncher

We first ran LENS for-credit with a group of 10 students in 2018. These students were from both Computer Science and Music. This pilot program used an existing group project course called *TechLauncher*, which was primarily designed to provide industry client-based tech entrepreneurship projects for later-year CS students. To fit LENS within this structure we assumed roles (client and tutor) usually filled by industry mentors. Our client brief: to provide the space to explore the creative potential of the technology they use every day—to make, break, mend, hack, learn and unlearn.

This arrangement was very flexible: the students had broad scope to make whatever they wanted, and the established enrolment process was particularly useful for the CS students (many of whom were required to take the *TechLauncher* course anyway). However, in comparison to the other groups within the program the LENS cohort was small, and their work wasn't easily understood by other groups engaging in peer assessment. The course's focus on process rather than product limited our ability to critically engage with the musical outcomes.

Figure 2. LENS developing a performance at Ainslie Arts Centre, 2018.

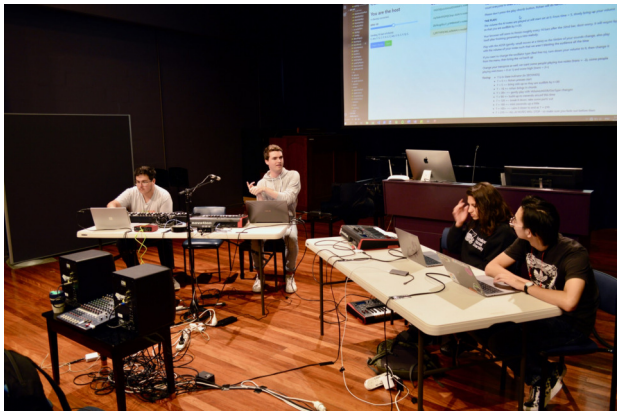

Figure 3. Joshua McConnell, Rohan Proctor, Kira Breithaupt and Weitong Huang rehearsing a LENS work, 2019.

5.3 Version 2: music and CS project

The present iteration of LENS (Semester 2, 2019) similarly reuses existing ANU course codes. Both the CS and music programs already contained open-ended course codes (*Special Topics in Computing* and *Music Project* respectively). Within these course codes, we arranged the LENS enrolment & assessment schedule so that each student developed an individual laptop ensemble project while performing and working together as a group. Both had summative assessment schemes with a 50% weighting on a project report (or process diary) and 50% on the practical outcome (creative practice or computing artefact).

Consistent with the appropriated course codes, we asked each student to create an individual laptop ensemble work to be performed at the end of the semester. To help fill in knowledge gaps for both groups of students we provided a crash-course in computer music through a four week seminar series at the beginning of the semester covering dig-

ital synthesis, algorithmic composition, interfaces, interaction and live coding. The first three topics were taught using Pure Data (https://puredata.info), while Extempore (https://github.com/digego/extempore) was used for the live coding material. We added bi-weekly process diary entries, a graded design motivation document, and performance at a work-in-progress concert (See Figure 3) to allow more opportunities for feedback to the students on how they are tracking.

This iteration of LENS has been broadly successful, with each student developing a composition and performing in the work-in-progress and final concerts. In contrast to version 1, we are able to assess the students creative and technical output, and to give feedback along the way. With four CS students and four music (composition) students involved, the LENS contains a mix of experience with computing and creative skills with both groups challenged to fill in their knowledge. The cracks in this iteration are related to the volume of material to be covered in order to create, implement, and perform a laptop ensemble piece. The crash-course could easily be a full course (as it is in many other institutions) and another full course could be devoted to the collaboration, performance and staging issues of computer music.

6. CONCLUSIONS AND QUESTIONS

Our attempts to bring musicians and computer scientists into a laptop ensemble have challenged us as educators, as well as challenging students on both sides. Similarly to other laptop ensembles we have experienced the tension between content delivery, workshop or studio time, and actual rehearsal of the performative outcomes. We see benefits for both cohorts of students, but it could be that computing students, starved of credit-earning creative courses, see the greatest benefit. Our attempts have brought us on a tour through multiple course codes; and while the present iteration is likely to have the most completed student works, we are already imagining what a more inclusive LENS course could look like.

The laptop ensemble as a phenomenon seems unlikely to go away. Music technology is now (probably, finally) unavoidable as a relevant focus of study in the academy. Computer science and "coding" has surged ahead as part of a new anxiety regarding STEM in all levels of the education system but concerns over how to shape well-rounded computer scientists and engineers may lead towards more focus on creative arts within these fields. While we acknowledge the danger of an creating an electroacoustic aesthetic wasteland, we feel that developing collaborative communities of practice with multi-disciplinary students is worth the risk, and the challenges of navigating university bureaucracies.

While we feel ill-equipped to conclusively evaluate our efforts, we present a number of open questions that have arisen so far in our work and that we are using to guide our ambitions for future iterations of LENS.

- How do we balance allowing the CS & music students to play to their strengths (tech, music respectively) while also encouraging (forcing) them to engage with the "other"[1] side of the course?
- How do we fairly assess group work in a heterogeneous student group, with very different experiences & expectations with regard to assessment, notions of quality/correctness/*goodness*?
- Can we scale the LENS experience to meet demands of large student numbers; in other words, can we run a LENS class with 50 students? What about 500?
- Can a LENS class give rise to a LENS *scene*? Can a course for credit interact successfully with an emergent artistic culture?

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COMPOSING SOUNDSCAPES FROM A SINGLE FIELD RECORDING

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ABSTRACT

This paper will discuss the multiple uses of a single original field recording in relation to the author's own work, with inspiration drawn from composer Joanna Bailie's works. Bailie views the prolongation of frequencies in field recordings as a way of "freezing" a section of time, to explore the essences of the frequencies found within a particular point in time - turning the moment into a decipherable stretch of time for the mind. This elongation also allows the exploration of emotion and musicality of a moment, by exposing hidden harmonies and rhythms. The paper will discuss methods of composing with a single field recording (time-stretching, layering, and the use of effects and panning), through examining two pieces from the author - *Corridor* [2018] and *The Insect Apocalypse* [2018] - and how such a process, with its combination of artistic and technological interventions, can also create pieces that mediate on the ecological stresses found within the original field recording.

1. INTRODUCTION

My start in field recordings began in 2015, as I began to explore ways I could incorporate my experiences in a place into compositions. While I was initially viewing field recordings as either recording-as-documentation or gathering sonic material, with the focus being on capturing impartial and neutral artifacts of soundscapes, I became increasingly aware of the role of field recordings as a form of personal expression. As I worked more deeply with field recordings, I became increasingly interested in the narrative side of my process - for instance, the reasons why I chose a particular place to visit and record, the sounds I was choosing to record and how I was using and arranging sounds to create the composition.

I found that the more I listened, the more I noticed the depths of complexity in the recorded sounds. I became interested in how manipulating sounds through the use of effects, time-stretching, and playing with time and asynchronicity, as though the layers were like multiple waves hitting and bumping into each other. I found I could layer these manipulated sounds with the original recording as a way of reflecting my experiences in the landscape.

This paper will be split into two broad sections – firstly, a discussion of composition using single-source field recordings, with a focus on UK composer Joanna Bailie, and secondly, a discussion of two of my works inspired by Bailie's approach - *Corridor* (2018) and *The Insect Apocalypse* (2018).

2. FIELD RECORDINGS AS NARRATIVE – A BRIEF OVERVIEW

Field recordings have been perceived as recording-as-documentation or as a process of gathering sonic material, with the focus being on capturing impartial and neutral artifacts of soundscapes. The narratives that exist within the recordist, however, have been generally less acknowledged. Isobel Anderson and Tullis Rennie noted in their article, *Thoughts in the Field: Self-reflexive narrative in field recording*, where they discussed notions around narrative in field recording: "These narrative details should certainly not automatically be silenced, repressed, or re-dated, which are common conventions within the practice. Instead, these insights can become some of the most interesting and creative elements of field recordings, both strengthening the field recording artist's understanding of their practice and providing greater potential engagement for listeners" (Anderson and Rennie, 2016).

There have been several composers who have explored field recordings as a form of self-reflexive narrative. Arguably, one of the earliest practitioners was French composer Luc Ferrari. Ferrari's first foray, *Presque rien, ou le lever du jour au bord de la mer* (Almost nothing, or daybreak at the seashore), recorded in Vela Luka, Croatia and released in 1970, was a demonstration of a field recording being used both as a part of composition and auditory memory making. While in Vela Luka, Ferrari spent several weeks exploring the village and surrounds with his partner, Brunhild Meyer Ferrari. As they explored the area, Ferrari became increasingly drawn to the sonic environment and his responses to what was happening, and recorded for several mornings. As noted by Lawrence English in his essay about the work, "In *Presque Rien No. 1,* Ferrari perceived that his listening, as an affective and agentive performance within a given horizon, was not absolute or ongoing, but rather highly

selective in attentiveness and temporality" (English, 2017).

Another example is seminal soundscape artist Hildegard Westerkamp, with works such as *Kits Beach Soundwalk* - where she explores her affinity with Vancouver's Kits Beach through a combination of field recordings and Westerkamp's spoken contemplations, which demonstrates, to the listener, Westerkamp's active role in capturing and reflecting on the soundscape. One point of particular interest with *Kits Beach Soundwalk* is how Westerkamp openly sign-posts to listeners her manipulations in the studio, such as informing audience she is diminishing the sound of traffic to amplify the sound of the ocean because the view is "…beautiful. In fact, it is spectacular" (Anderson and Rennie, 2016).

In a similar vein to Westerkamp, Janet Cardiff also establishes herself within soundscape recordings through her series of soundwalk compositions, where she narrates over a composed soundscape. In works such as *A Large Slow River*, Cardiff uses Lake Ontario as a setting for discussing memory and time. For instance, in one passage Cardiff narrates over the sound of crashing waves: "I'm at a beach on Lake Huron, my toes squishing into the mud…jumping off my father's wet shoulders into the water. Now I'm at another beach, it's night, the sound of the waves coming in through the screen windows" (Cardiff, accessed September 1 2019).

Manipulating the temporalities within recordings themselves is another way in which composers can use field recordings as self-reflexive narration. A prominent example is Barry Truax, who explores temporality and narrative through the elongation of field recordings. Truax explains his technique as a way of revealing "...the inner harmonics within familiar sound signals...My intent was to use the suspension of these sounds to give listeners the space in which to explore their own inner associations..." (Truax, 1992).

One example of this is *Pacific* (1990), with the first movement *Ocean* based on a recording of waves hitting a sandy beach. *Ocean* begins with the waves played at normal speed, but gradually stretched until it gives the listener the sensation of a "gradual submersion beneath the waves as their inner timbre is revealed…" (Truax, 1992). The process of submersion, as Truax explains, "…is accompanied by the loss of the rhythmic pattern of the waves, which further heightens the illusion of entering a normally hidden realm" (Truax, 1992).

The idea of slowing recordings as a way of revealing hidden sounds is taken further by composer Joanna Bailie.

3. JOANNA BAILIE

Joanna Bailie is a composer and musician originally from London, but now based in Berlin. Her recent works include chamber music and installation and are characterised by her use of field recordings alongside acoustic instruments. Bailie's passion lies in exploring the ways in which elements of the 'real' world can be recorded, then manipulated and transcribed for acoustic instruments to be performed alongside the processed field recording itself. For Bailie, this process allows a "…fashioning [of] a more complex relationship [between sound and listener] that lies beyond the idea of a simple immersion into a pseudo-reality" (Bailie, 2014).

Bailie describes one of her first experiences with field recordings and what initially drew her towards her approach:

> *I remember once sitting at a bus stop recording the cars go by and at one point there was a shift in my perception, perhaps due to my level of concentration or the effect of amplification. I genuinely had the impression that the cars were driving past a particular times, speeds and volumes for precisely my own pleasure, that it sounded good and that it was indeed music* (Power, 2014).

Similar to Truax, Bailie employs time manipulation techniques where she elongates sounds to, in her words, "…allow for the exploration of emotion and musicality of a moment, by exposing hidden harmonies and rhythms". (Bailie, 2014). The resultant composition is one that is filled with technological and artistic intervention by the artist, rather than it being a reflection of the original subject of the sound recording. Bailie explains, "A possible approach may be to actively look for music when making field recordings or to tease the music out of the recording by some kind of manipulation. For me it's a question of an appealing dramaturgy that might itself suggest a compositional strategy, a certain (fortuitous) balance of elements and more often than not, pitch content, whether it comes in the shape of music in public spaces, car horns or airplane drones."

Bailie terms the process of elongating sounds as 'freezing', and describes the concept while discussing the processes behind one of her pieces, Artificial Environment No. 3:

> *Artificial Environment No. 3 is a place where time is stopped and started in an aperiodic and therefore unpredictable manner. As frustrating as this must be for its inhabitants, it has a rather curious effect on sound. At the moment of freezing, a split second of sonic resonance is prolonged until life resumes again from the point where it was broken off. Even stranger is the effect that these freezes have on the general ambience. Sounds start to behave like an inappropriately sentimental soundtrack. A bell, a passing car, or a fragment of birdsong are given an air of gravitas and occasional nostalgia simply by being taken out of the continuum of everyday life and stretched into a chord* (Power, 2014).

For Bailie, the process of 'freezing' becomes a method of revealing aspects about the world that might

otherwise escape perception. She notes that by transforming an 'instant' – that is, an event of such short duration that it becomes imperceptible – into a longer 'moment', it allows the event to inhabit the mind and become accessible to memory. Bailie elaborates on this in an article about her process: "…it might lead us to think about some of the emotions that are evoked through the prolongation in time of a split-second…" (Bailie, 2014). Often Bailie combines these elongations together intuitively, following the flow of a narrative over any temporal hierarchy.

4. WORK 1: CORRIDOR

I found Bailie's work particularly inspiring because of her desire to explore the emotionality behind sound through probing the sonic nuances that lie within a recording. There is a powerful evocativeness in Bailie's work - from its source from real, occurring events to the strange, dissonant and surprisingly melodies and rhythms that are teased out from being 'frozen'. I have also become increasingly preoccupied with climate change and wanted to use field recordings as a way to discuss environmental concerns.

One piece I wrote that was inspired by Bailie's approach was *Corridor*[1]. *Corridor* is a piece exploring the use of a single sound source to construct a soundscape - as though the sound is mediating on itself. This piece is also about movement, loss and attempting to preserve what was left.

The original field recording was made in an underpass in Neerabup National Park, in the northern suburbs of Perth, Western Australia. Neerabup is an important stretch of bush for two main reasons - firstly, it acts as a wildlife corridor for native wildlife (particularly the many native birds), connecting two important wetland areas in Lake Joondalup and Loch McNess. Secondly, it incorporates and protects part of an ancient Aboriginal migration route, which is now a walking trail called the Yaberoo Budjara Heritage Trail.

When composing this piece, I wanted to explore the juxtapositioning of an historically and ecologically important area within a busy transport network. This particular section of Neerabup National Park is bisected by Neerabup Road, a busy road which provides access to the Neerabup industrial area. Bordering Neerabup National Park are two main roads – the Mitchell Freeway, and Wanneroo Road – plus the train line.

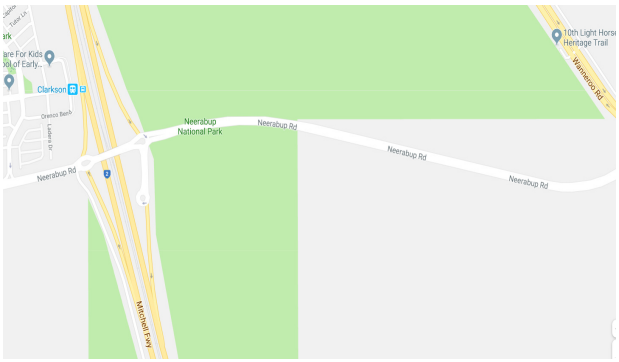

Figure 1. A map of the area where the recording was made, showing the roads that bisect and border Neerabup National Park (Map data: Google).

The initial recording was made during the afternoon, when traffic was busy. In the original recording, the sound of birds and swaying trees can be heard in the background, with the sounds of vehicles passing threatening to overtake these sounds. I felt this recording was a microcosm of the continual tensions between preserving and protecting the ecosystem with humanity's need for development, and wanted to explore this further in the composition.

One aspect I wanted to accentuate in the piece was the deep drones of the vehicles as they drove over the overpass, so I slowed and pitch-shifted the original recording in Adobe Audition by various degrees (800%, 600%, 400% and 200%). I also added a doppler effect (also in Adobe Audition) to one of these versions to replicate the sound of wings flapping, as a way of representing the movement of birds through the wildlife corridor. These various versions were then layered with the original in Ableton Live. The layering of tracks was my way of playing with temporality – I viewed the building of the composition as though they were waves tumbling through and onto each other as they approached land, each in their own as they individually navigate the geography of the sonic shoreline.

The final composition consisted of eight layers, with the following effects:

Layer 1: Original recording
Layer 2: Original recording + delay
Layer 3: Excerpt from original of cars passing, slowed 800%
Layer 4: Layer 3 + resonator
Layer 5: Excerpt from original of cars passing, slowed 600%
Layer 6: Excerpt from original of cars passing, slowed 400%
Layer 7: Excerpt from original of cars passing, slowed 200%
Layer 8: Layer 7 with doppler effect

[1] Full piece can be heard here: https://samarobryn.bandcamp.com/track/corridor-disquiet-0348

5. WORK 2: THE INSECT APOCALYPSE

The Insect Apocalypse is a series of two pieces, based on a recording of crickets outside the front of my house. The title of my piece references an article called 'The Insect Apocalypse Is Here' where insect populations around the world have dropped dramatically in recent years due to human-related reasons (Jarvis, 2018). I was inspired to ponder how an 'apocalypse' might sound and feel like from an insect's perspective. *The Insect Apocalypse* is split into two sections:

The Insect Apocalypse: a piece imagining how the 'apocalypse' is perceived as it is happening, and therefore features mechanical-like sounds as a way of representing human machinery and interference.

Heart Of The Apocalypse: a piece that imagines how the internal experience of the 'apocalypse' might be experienced by an insect as it slowly dies.

The first track of the series, *The Insect Apocalypse*[2], features a field recording of crickets in the foreground with sounds of passing traffic in the background. I wanted to create a mechanical droning sound to the piece as an ominous backdrop, so I pitch-shifted and slowed the original recording in Adobe Audition by 1200% and 800%, and added a doppler effect to one of the versions. The rest of the composition was completed in Ableton Live, where I added delay, panning, resonator and distortion effects to further invoke a threatening soundscape. I was particularly drawn to using panning effects and arranging sounds in an asynchronous manner (i.e. playing two versions of the same sound, 30 seconds apart) to create an immersive and dissonant experience for the listener.

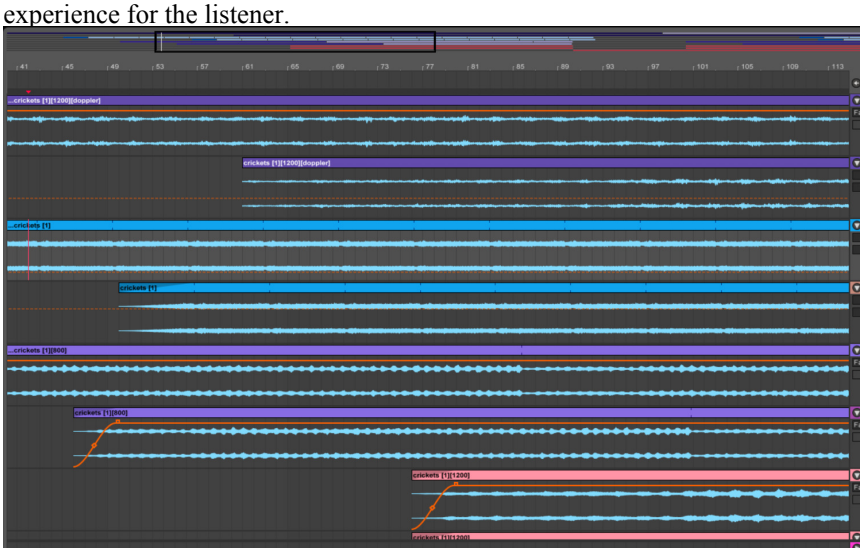

Figure 2. Screenshot of the construction of *The Insect Apocalypse* in Ableton Live, showing some of the tracks being layered in an asynchronous manner. This screenshot is taken from the beginning of the piece, with the first six layers.

The final composition consisted of nine tracks:

Layer 1: Original recording slowed 1200%, with doppler effect
Layer 2: Original recording slowed 1200%, with doppler effect, Moscow resonator, distortion and Wanderer delay effect
Layer 3: Original recording with Around The Head panning effect
Layer 4: Original recording with Around The Head panning effect and Low Tone Flutter grain delay
Layer 5: Original recording slowed 800%, panned 90-degrees left with Sennheiser AMBEO Orbit (for binaural panning)
Layer 6: Original recording slowed 800%, panned 90-degrees right with Sennheiser AMBEO Orbit
Layer 7: Original recording slowed 1200%, with Mirage bit reduction and panned 45-degrees right with Sennheiser AMBEO Orbit
Layer 8: Original recording slowed 1200%, with Swirling phaser and panned 45-degrees left with Sennheiser AMBEO Orbit
Layer 9: Original recording slowed 1200%, with Moscow resonator and reverb.

The second piece in the series, *Heart Of The Apocalypse*[2], continues in same vein but with a singular "frozen" cricket chirp recording taken from the original field recording of the crickets in my front yard. For this piece, I was particularly drawn to Bailie's ideas behind her *Artificial Environment* series, where she noted how elongation exposed the hidden complexities within an otherwise short sound.

The original cricket chirp lasted less than a second, but using Adobe Audition, I was eventually able to stretch the sound to nearly 9 minutes. After this pitch-shifting, I experimented with the graphic equalizer option to cut out specific frequency bands and was struck by the complexity of the revealed harmonies. Organising the resultant versions of the elongated field recording was reminiscent to arranging an eerie choir.

The final composition consisted of seven layers, with the following effects:
Layer 1: Time-stretched recording of cricket chirp (used as the foundation or "base" of the composition) with Around The Head panning effect
Layer 2: "Base" recording with

[2] Full piece can be heard here: https://samarobryn.bandcamp.com/track/the-insect-apocalypse

[3] Full piece can be heard here: https://samarobryn.bandcamp.com/track/heart-of-the-apocalypse

Figure 3. Screenshot of the construction of *The Heart Of The Apocalypse* in Ableton Live, showing how some of the variations of the field recording were layered. This screenshot starts at beginning of the piece, with the first six layers.

Ring frequency shifter effect
Layer 3: "Base" recording filtered at 250hz
Layer 4: "Base" recording filtered at 500-710hz and panned 45-degrees left with Sennheiser AMBEO Orbit
Layer 5: "Base" recording filtered at 500-1000hz and panned and panned 45-degrees right with Sennheiser AMBEO Orbit
Layer 6: "Base" recording filtered at 250hz with Five grain delay, distortion and Around The Head panning effect
Layer 7: "Base" recording with Frozen Build Up reverb effect, distortion and Around The Head panning effect

6. CONCLUSION

Basing a composition on a single field recording can allow a deep engagement with the recording itself, particularly when combined with technological and artistic intervention by the artist. Methods such as time-shifting allows an artist to dive into the hidden resonances and harmonies behind instances in time, while also allowing artists to engage with the history and ecology of the area itself. In my own practice, I have found this level of engagement valuable in constructing narratives within my compositions, and for reflecting on my motivations of creating a piece. These methods can be avenues for reflecting on fieldwork and knowledge gained in the field – for instance, part of *Corridor* is also about acknowledging the local history of the area and the importance of its continual existence.

This style of composition – and more broadly, a more self-reflexive style of working with field recordings – also allows artists a way of drawing attention to current concerns. The Insect Apocalypse series is, at its heart, a series about the increasingly urgent issue of climate change. The sounds in the series are deliberately discordant, haunting and harsh, to highlight the uncomfortable reality that the world is heading towards a crisis.

Ultimately, this approach to field recording – with its emphasis on self-reflexive narrative – can create multi-faceted works that can trigger strong emotional memories and associations in listeners. This method also highlights the active agency of the artist by acknowledging the emotive responses behind the recording (and creation) of a soundscape.

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SMALL DIFFUSION, BIG IMPACT: COMPOSING IMMERSIVE ACOUSMATIC MUSIC FOR THE NON-IDEAL LISTENING SITUATION

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ABSTRACT

Acousmatic music is increasingly composed with the artistic goal of diffusion through large or complex speaker arrays, over more accessible methods such as the diffusion of mono or stereo works through headphones or other small devices. In this paper, the term "small diffusion" is introduced to describe simpler, often more intimate listening experiences. By awarding a collective label to more portable or accessible methods of acousmatic listening, small diffusion methods are raised to an equal level of legitimacy as more complex diffusion systems in our increasingly technological listening environment. The concept of the non-ideal listening space is argued as a valid and interesting space for acousmatic music. I include two examples of my work composed for small diffusion and non-ideal listening spaces: Paranoia in the Bush and 3 miniatures for headphones. These works engage with the challenge of maintaining spatial and musical immersion despite the possibility of increased distractions and technical obstacles in the small diffusion space, and are thus composed for a larger and more likely range of listening situations to demonstrate a method for increasing access to modern acousmatic music outside of the academic sphere.

1. INTRODUCTION

Music composed for stereo diffusion was a staple of electroacoustic music practice in the 1960s (Austin 2000). Now, acousmatic music is increasingly composed with the artistic goal of spatial immersion, often via large speaker arrays ranging from 5.1, through to Ambisonic arrays using tens of speakers. Composing works for large diffusion systems in concert-style performance is believed to enhance the audience's musical immersion, appreciation of structure, morphology and technique, making it preferable to composing mono or stereo works for accessible playback systems and equipment such as home computers, stereo speakers and headphones (MacDonald 1995). This paper challenges the notion that bigger is always better (immersive, valuable, artistically powerful) when composing acousmatic music. I put forward two new concepts for consideration which have the potential to re-imagine the acousmatic genre for solo listeners and small groups, recalling the great ability of recorded music to bring new musical genres to the wider public (Millard 2005). In this paper, I offer two musical examples to demonstrate these concepts in action: my recent works *Paranoia in the Bush* and *3 miniatures for headphones.* These works employ different compositional and spatial techniques intended for ubiquitous playback tools, such as headphones, to create immersive acousmatic music.

The issue of creating realistic and immersive space in acousmatic works is already quite widely discussed; in particular, the obstacles inherent to stereo and mono diffusion. In "Ambisonics and Acousmatic Space," Natasha Barrett (2010) writes that it is crucial for a listener to place themselves within a space before they can appreciate musical content, suggesting that the discrepancy between real-world spatial perception and that allowed by traditional diffusion systems, i.e. stereo or multi-channel, may be a contributing issue. Alistair MacDonald (1995) similarly asserts that listeners subconsciously judge electroacoustic music by different standards to instrumental music; while one would not question the real-world source of an oboe note, one struggles to relate abstract acousmatic sound to any real-world source object. This arguably makes real-world spatialisation an important tool for engaging the uninitiated. Macdonald (1995) lists multiple issues encountered in stereo speaker diffusion for large audiences: a limited sweet spot; varying distances from the speakers; and a reduced "level of engagement" for those listening from the sides of the stereo image. Mark Nazemi (2014) writes on immersive soundscapes as a method of chronic pain alleviation, and identifies spatial concerns such as differences in Head-related Transfer Function (or HRTF, a result of an individual listener's head, ear and facial formation which affects how sound is perceived and localised) which result in unrealistic sound localisation and hence decreased listener immersion.

It is certainly possible to create realistic headphone spaces through binaural and Ambisonic mixing; these give the impression of sounds occurring from beyond the physical scope of the headphones, as if from a real-world source. The purposeful panning of sounds to be perceived as coming from inside the head is known as in-head acoustic imaging (IHAI). IHAI is defined by Charles Stankievech (2007) as creating an imaginary sounding space within the listener's body. Used artistically by composers such as Ryoji Ikeda and Bernard Leitner, the head cavity is made to sound hollow, while sound objects resonating within this

imaginary space are heard from within by the outside ear (Stankievech 2007). Being quite removed from real-world experience, this unique space eliminates the concern of localisation issues caused by HRTF, inter-aural amplitude and time differences (Stankievech 2007). Nazemi (2014) lists IHAI (which he names the "sound-in-head" phenomenon) as an obstacle to achieving realistic space. Re-framing IHAI as a non-realistic but imaginative spatial technique allows composers to exploit spatial quirks in relatively cheap technologies to create fantastical spaces - which are immersive in their own right.

2. SMALL DIFFUSION

Denis Smalley defines diffusion as "the projection and the spreading of sound in an acoustic space for a group of listeners — as opposed to listening in a personal space" (Austin 2000). Considering this accepted meaning, "small diffusion" may seem like a misnomer. However, diffusion has multiple definitions with slight variations for different contexts; the Oxford Dictionary calls it "the spreading of something more widely." Small diffusion can therefore be taken as a dual term describing not only the physical phenomenon of listening to acousmatic music on portable, accessible diffusion systems, as well as a cultural one: embracing the use of readily available technology as a valuable and legitimate way to make acousmatic (or indeed, any) music.

Due to the nature of affordable technology (such as headphones, CD players, phones, laptops, etc.) the term suggests a listening experience for small groups or individual listeners. While this concept isn't quite the antithesis of the group listening experience, this approach does not require specially built auditoriums or expensive sound apparatus, leading to a natural association with non-specialist or even low-quality equipment, and non-ideal listening conditions such as the presence of external noise, visual distractions, etc. The use of readily accessible equipment to create music is a crucial feature of Ubiquitous Music, which according to Marcelas S Pimenta et al. (2009), "can be defined as musical computing environments that support multiple users, devices, sound sources and activities in an integrated way." Lars Holmquist introduced the term to academic literature in 2005, writing that society lives with access to a "limitless supply of music." Inevitably, this suggests that music will be increasingly "experienced in [physical] isolation," again highlighting how composing for small diffusion might be of benefit for an acousmatic composer hoping to disseminate their work (Holmquist 2005).

However, this boundless portable music supply does not have to be isolating; multiple studies have shown that synchronised movement or dance performed at silent discos results in increased feelings of "social closeness" in listeners (Tarr et al. 2015). Interaction design has progressed to the point that several systems will allow users to "listen in on" others' broadcast devices, which holds (apart from social and security difficulties) great potential for small diffusion listening to become a group experience, while still a deeply personal one (Holmquist 2005).

Nevertheless, small diffusion is a suitable choice for intimate, close listening. Andean (2014) describes the possibility of the listener "hijacking" the composer's intentions with their own unique interpretation of an acousmatic narrative. Art theorist Stephen Scrivener (2002) takes a more pacifist approach, attesting that the end-point of art is not to communicate absolute knowledge, but to encourage the consumer to devise one of many interpretations. Composing for intimate or solo listening (or individual experiences in a group setting, such as the systems described above or Silent Discos) enhances the listener's ability to respond independently and uniquely to the acousmatic. Therefore, it would seem fitting that there should be a name for listening methods which encourage this specifically individual response.

It should be noted that it would be short-sighted to discount the vastly different considerations which make up the evaluation of acousmatic works as compared with the rest of the Western musical canon. The manipulation of space is one of the foremost, or as Smalley (2007) describes it in his seminal work, Space form and the acousmatic image, "aesthetically central." However, that is not to say that small diffusion methods do not retain an important space in electronic art music, not only through its own artistic potential (a discussion which is owed its own paper), but for the sake of accessibility.

2.1. Accessibility

"Accessibility" in this paper refers not to how approachable the acousmatic work is, but to technological accessibility: creating works which are easily diffusible on mediums used by the wider community, in a traditionally and increasingly multi-channel practice. Andean (2012) writes:

> *If one is concerned about making music cross-culturally communicative, there is more urgent need for a bridge between the acousmatic community and the uninitiated.*

Given these observations and critiques, optimising some acousmatic works for easily accessible mediums may be the first step. When first introduced, recorded sound was a "great educator," which allowed the musically curious to learn and pursue music of different cultures and styles (Millard 2005). It encouraged the spread of music which could not be documented by existing Western notation, allowing the development and fusion of multiple genres to take place (Millard 2005). The rapid expansion of affordable, portable music technology has enabled music to be listened to anywhere; hence recorded sound is better able than ever before to disseminate non-notated genres such as electroacoustic music (Holmquist 2005).

One great benefit of using small diffusion methods is portability. A monophonic or stereo image is easily transmitted over radio, CD player, studio monitors, or indeed headphones, which can be found almost anywhere in the world. David Berriman (1998) explains that headphones can be preferable to speakers in many instances; for example, they avoid room and box resonances, hence giving an experience which is truer to the original recording. MacDonald (1995) stresses the importance of space to a listener's interpretation:

> *For even if the composer carefully considers space and spatialisation…as soon as a piece is played in another room, many aspects of the sound are subject to the acoustic qualities of that room.*

Composing for headphones eliminates this concern; the composer who makes music with and for headphones will be able to guarantee quite closely what the listener will hear. Berriman (1998) does concede, however, that headphones may not communicate the same intangible sense of power and bass rumble that speakers will, a lost opportunity for enhanced immersive effect.

3. PARANOIA IN THE BUSH

Since the rise of stereophonic sound in the 1950s, headphones have maintained a steady stake in the listening landscape as ideal vessels for stereophonic listening (Berriman 1998). Therefore, it is in my interest to explore composition for diffusion methods such as stereo speakers and headphones, broadening what MacDonald (1995) boldly describes as the "limited appeal" of electroacoustic music through the accessibility of small diffusion and consideration of likely listening spaces. As an acousmatic composer, I have decided to explore headphone music as a widespread example of small diffusion.

My composition *Paranoia in the Bush* (2019)[1] seeks to represent a variety of sensations experienced while walking alone in the Australian bush – ranging from the frenetic paranoia to meditative tranquility. I exploit IHAI to increase the sensation of uncanny happenings and irrational imagination. The work features sharp cuts between contrasting sounds, frenetic pacing, and occasional moments of calmer, extended field recordings captured at Bundanon Trust, NSW. Without explicitly referencing it, this work was strongly influenced by Bernard Leitner's *Kopfraume* album (2003), which specifically showcases IHAI through simple examples like hand-beaten drums.

No binaural spatialisation was necessary for this work; detailed manual automation of the Standard Panner parameter in Cubase (set to Equal Power pan law) was used to achieve IHAI. As with all acousmatic works, it was necessary to balance a demonstration of spatial characteristics, restraint and subtlety to avoid aural and mental fatigue. A sense of distance and resonance is achieved through a combination of reverbs, panning and EQ; though rather than perceiving sound as far away from the body, the listener may perceive the sound as being far on the perimeter of the sounding space which is inside of them - yet somehow larger than reality.

To enhance the immersive performative experience of this work at its premiere (at a bustling experimental music concert), the listener was invited into a small camping tent decorated with string lights and a bean bag seat, with noise-cancelling headphones provided to listen to the piece.

4. THE NON-IDEAL LISTENING SPACE

By carving out an individual space apart from the existing environment and eliminating external noise, visuals and nosy concertgoers (all potentially distracting), the listener is presented with the *most* ideal listening space for this work.

The Non-Ideal Listening Space (NILS) is a subjective concept whose definition may vary for each composer. A general definition of a NILS might be: a listening situation which poses a risk of distraction to the listener, or non-ideal conditions for performance of a work. Equally, the NILS might mean any scenario outside of a concert hall, studio, or certain site that a work is composed for. Distraction can come in many forms: sensory, sound, light, mental or physical discomfort, and so on.

While small diffusion and the NILS space are two discrete concepts, they often co-exist. Due to the portable nature of small diffusion mediums, it is likely that small diffusion works will be listened to in a NILS. It therefore seems logical for composers to engage with this possibility in the creation and performance of recorded works, no matter what diffusion system their work is intended for. Composers engaging in the medium of small diffusion, in particular, may react to the NILS in two ways:

- By embracing it, and incorporating aspects of the NILS into their work. This may include site-specific performances, Sound Walks, or works which are intended to mingle or react to their sound/physical environment.
- By acknowledging the potential of a NILS and attempting to eliminate its possible distractions. This may include immersing the listener in a *different* sound space; the use of noise cancelling headphones and physical segregation at the premiere of *Paranoia in the Bush* is one example.

It may seem easier to describe a NILS than it does an ideal listening space; even when every care is taken, distraction is often out of the composers' hands, or requiring "technically complex solutions" (MacDonald 1995). As Denis Smalley is quoted by MacDonald (1995):

[1] *Paranoia in the Bush* can be accessed via the following link: https://www.alexismarieweaver.com/small-diffusion-works.html.

Both the personal listening space and the diffuse listening space are open to widespread abuse which determines spatial perception.

Therefore, perhaps it is more accurate to say that all performance spaces exist on a spectrum from the most NILS to the most ideal, dependent on a combination of environmental, personal and musical factors. The personal is entirely up to the listener, their level of engagement and ability to perceive the work. Similarly, the wealth of existing listening modes can be put into a series of spectra or grids which show both the listener's level of attention to a sound and "listening intention:" a subjective frame imposed by the listener, through which a sound object is perceived (Chion 1983). Michel Chion (1983) explains that Schaeffer's "reduced listening" is yet another kind of listening intention. Steven M Miller (2014) writes that, as humans, we switch between listening modes constantly. Chion's (1983) quadrant of listening modes are arranged as a "circuit" with each mode "involved simultaneously, interacting with each other." In the same way, listener immersion while in a NILS may fluctuate between almost total distraction from, and almost total focus on the musical work.

The following listening modes do not attempt to replace any of the wealth of existing listening modes outlined by other authors and practitioners, but to highlight environmental distraction as an important factor in the perception of a musical work.

4.1. Peripheral Listening

The composed work mingles with the ambient soundscape; the listener may be focused on another task or activity. Barry Truax (2001) describes "Background Listening" similarly: the sound is an expected element within the overall soundscape. Chion (1983) describes the "perceiving" listening mode as "the most elementary level…passive," whereas the "hearing" mode notices more important sounds, but does not necessarily infer anything from them. Peripheral Listening is more engaged than "perceiving" or "hearing;" examples might be an innocuous as radio or television in the background; music accompanying a religious ritual; or an ambient soundscape in a museum. Brian Eno's Ambient 1: Music for Airports (1978), described by Mark Richardson (2002) as "background enhancement," might fall into this category as an example of composing music for a non-ideal mental space – that is, a busy airport full of rushing and anxious people. It can be merely heard, it can be listened to, but adds something of value to the soundscape at all attention levels.

4.2. Central Listening

The listener intends for the composed work to have their undivided attention. Composers intending to eliminate the effects of the NILS attempt to draw the listener into this mode, falling in with most musical performances and works.

4.3. Dual Listening

The composed work fits into the real-world soundscape but exists as equal to the listener's attention, providing a framework for environmental sounds to fit in. Most likely a site-specific work, the composed work and environment are both the focus, working together to create the finished work. Sound Walks might fit into this category, often working with the visual environment to augment the listener's reality. Guitarist Sebastian Sequoiah-Grayson (2019) performed a series of live improvised guitar sets with ambient street noise broadcast into the performance venue; another example of how the ambient environment can contribute to, rather than distract from, the musical product.

These listening modes describe the level of engagement the listener has with the work, and the interaction of outside influences, or distractions. As discussed, small diffusion methods are likely to be used by listeners outside of a traditionally ideal listening space, causing elements of a NILS to impact upon the final listening mode of the listener. As such, these modes can be a useful framework for composers using small diffusion methods, allowing them to gauge the final listener's experience, and if necessary, adjust it. Depending on the specific technology used (which may be governed by the listener, depending on their agency), small diffusion can enhance the NILS for artistic purposes, or almost mask it completely. Therefore, the composer can use small diffusion to push listeners toward the listening mode they wish to engender.

5. 3 MINIATURES FOR HEADPHONES

My composition *3 miniatures for headphones* (2018)[1] aims to distract from distraction through its boisterous content and composing techniques. Like *Paranoia,* it therefore aims to incite a Central Listening experience. *3 miniatures* is a triptych composed for a specific NILS; in this instance, a concert space during interval. I knew the following of the space:

- It would be loud;
- It would be bright;
- Audience goers would be moving around the space, most likely conversing loudly.

3 miniatures were thus created to work within these parameters. Extremely soft dynamics and delicate textures were deemed inviable due to the danger of being inaudible. I decided to use attention-grabbing, or what I term "obnoxious," techniques such as hard left-right panning, strident frequencies and rapid switches between textural states. While I chose high-quality, close-backed headphones for this installation, the work was thus insured against the use of other non-noise cancelling headphones. A short, sharp structure was chosen to capture the audience's fleeting attention. Each miniature

[1] *3 miniatures for headphones* can be access via the following link: https://www.alexismarieweaver.com/small-diffusion-works.html.

is complementary, yet autonomous; the listener is free to listen to one or three before re-joining their companions.

The audience were instructed to use the provided headphones and press play on an old, early 2000s model CD player. The method of delivery and cheap burned CD together imparted a subtle crackling layer over the existing sound, adding a pleasant, unexpected depth to the texture which would not have happened if using a larger diffusion method.

6. CONCLUSION

It is crucial that modern composers of acousmatic music ask themselves, "where do I want my music to be listened to? By whom, and how?"

This paper does not strive to discount the vast opportunities for impact and immersion that large diffusion systems offer the listener. Nor does it strive to present definitive answers to the ongoing question of listener immersion and engagement across simple and complex diffusion systems. It does seek to open a robust discussion on the importance of the small diffusion space and the place they might hold in the future of acousmatic music.

Small diffusion and the NILS have been introduced as new terms to legitimise and encourage thought on the accessibility, portability and sustainability of new electroacoustic music. Composers may engage with one or both concepts, and still render their music more portable; considering the interaction of both can give the composer substantial control over the reception of their work outside of the traditional concert hall. The three introduced listening modes aim to assist the composer in choosing their desired interaction with (or mitigation of) what may be an unknown listening environment.

Moreover, these concepts encourage and challenge composers to create immersive music with what might be relatively simple or limited techniques. I have put forward two works as examples, with the hope that this will inspire more small diffusion works and a variety of interactions with the NILS. Composers may therefore harness the growing reach of playing devices to expand their listening community, and increase awareness and appreciation of the incredible genre of acousmatic music.

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ANALOG ALGORITHMS: GENERATIVE COMPOSITION IN MODULAR SYNTHESIS

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ABSTRACT

The contemporary re-emergence of modular synthesisers as a popular tool for music making rejects much of the conveniences afforded by advancements in music technology in the past 40 years, an idea that challenges our understanding of the relationship of electronic music composers to technology. Given the dominance of the computer in music making since the early 1990s there is a temptation to situate the modular synthesiser in opposition, focusing upon the modular instrument's tangible interface and a general shift away from the ubiquitous computer as primary drivers for the return to modular synthesis (Paradiso 2017). I argue that generative compositional approaches, specific to modular synthesisers, are another factor that should be considered in relation to this re-emergence.

The modular synthesis paradigm foregrounds generative compositional processes designed not only to create sound, but to generate musical events and control signals. Many module designs carry a legacy of generative processes that can be traced back to the earliest commercial synthesisers. These generative approaches exhibit attributes that are intrinsically distinguishable from those developed in the field of computer music.

1. INTRODUCTION

Modular synthesisers have recently re-emerged as a popular tool for electronic music composition (Roads 2015, 88). Paradiso argues that the causes attributed to this renewed interest are driven by a desire for tangible interfaces, a reaction to the omnipresence and continual obsolescence of computers and software, the collecting behaviour of consumers, and the democratisation of the design and manufacturing processes used (Paradiso 2017). This paper argues that another, largely overlooked, factor in the contemporary resurgence of modular synthesisers is the generative compositional strategies they afford.

In the following section, a historical context is provided emphasising a shift in the popular understanding of what a synthesiser does or is designed to do. An analysis then follows of the historic discourse associated with several significant instruments, revealing a paradigm of algorithmic electronic composition that has developed since the 1960s (Bode, 1961). Several generalisable experiential attributes identified through my own reflective practice of using modular synthesisers are then described. This serves firstly toward understanding the possible impact of these generative compositional processes, and secondly, toward a broader understanding of the recent resurgence in the use of modular synthesisers.

2. HISTORICAL CONTEXT

It is generally accepted (Manning 2013) that Harald Bode designed and built the first modular synthesiser in 1961. Bode credits analog computing as the inspiration for the modular approach, enabling the creation of "intricate electronic systems from modules with a limited number of basic functions" (Bode 1961, 5). Donald Buchla and Robert Moog then went on to develop and commercially release their own modular synthesiser[1] designs in 1966 (Manning 2013, 102).

Up until the early 1970s these large, expensive instruments experienced a level of commercial success (Vail 2000, 41), in particular, Moog's company R. A. Moog Inc benefited from the attention generated by the hit record *Switched on Bach* by Wendy Carlos (Vail 2000, 41). Buchla was less concerned with commercial success (Pinch and Trocco 2004, 33), coming from the perspective of a tape music composer with an interest in John Cage and indeterminism (Goebel & Rockwell, 2008, p. 173) and embedded in the counterculture movement (Pinch and

[1] The term 'synthesiser' is deliberately used throughout this article in its contemporary usage encompassing a range of instruments and methods. The term was used by Harald Bode in his article *Sound Synthesizer Creates New Musical Effects* (Bode 1961). Donald Buchla used a range of other terms including 'Buchla Box' (Pinch and Trocco 2004) and 'Modular Electronic Music System' (Buchla 1966) and there was likely an intention behind this terminology, however, the term has since stabilised to describe most electronic instruments that formulate audible waveforms.

Trocco 2004, 35). Whilst Moog's modular synthesiser sales dropped off sharply in 1970 (Vail 2000, 41), a new instrument design, the portable Minimoog D, was building momentum and would eventually be sold in the tens of thousands (Holmes 2015, 268).

The Minimoog D had a number of advantages over the larger modular instruments; it had a fixed architecture design, with standardised connections between components, greatly simplifying its design. The inclusion of an integrated keyboard interface made its function more apparent to potential users (Paradiso 2017, 2), particularly as a performance instrument. The instruments smaller size allowed it to be portable and its cost made it more accessible. The success of the Minimoog drove other companies to develop similar fixed architecture, keyboard based instruments such as the ARP Odyssey (Pinch and Trocco 2004, 265). These new, compact designs forgoed much of the flexibility of the proceeding modular designs (Holmes 2015, 248) and firmly established the keyboard as the standard interface for synthesisers (Pinch and Trocco 2004, 8).

Jumping forward to 1983, the MIDI standard was established (Manning 2013, 267), the *note on, note off*, paradigm drawn directly from the piano keyboard (Dalgleish 2016). The ubiquitous and relatively consistent nature of the MIDI protocol paved the way for a more complete separation of interface and instrument, enabling sound modules and rackmount synthesisers to be developed that were entirely dependent on external MIDI control or sequencing devices in order for sound to be emitted.

The preceding compressed historical narrative highlights a cementing of the definition of *synthesiser* as a device that produces sound (a sound engine), and a conceptual separation of the sound engine from devices that provide musical or other controlling data such as keyboards or sequencers.

Various synthesizer instruments have included sequencing or arpeggiator devices capable of controlling the synthesiser sound engine, some of these sequencers such as the Roland TB-303 exhibit unique attributes, and may be perceived to contribute key qualities to the instrument's character. In these cases the conceptual separation of controller and sound engine persists as the sound engine cannot impact upon the operations of the sequencing device, the relationship of control is in one direction, and the two processes of sound producing, and event and parameter control generation, remain distinct.

3. ANALOG ALGORITHMS

Timing event generators and sequencers were an integral component of the first Buchla synthesiser (Vail 2000). The design impetus came from tape music practices, as a means to speed up compositional processes through the automating of *sequences* of pitch and amplitude changes (Hanson 2010, 18). Three sequencing modules were included in the original Buchla 100 (also known as the Buchla Music Box or the Buchla Electronic Music System), two Model 123 Sequential Voltage Source modules with 8 stages, and the 16 stage Model 146 Sequential Voltage Source (Vail 2000, 107). The modules were identical aside from the number of stages offered (H. Howe 1967, 24), both offering 3 voltage level outputs per stage and a rotary switch to limit the number of stages. A timing pulse triggers the modules to select the next set of voltages, after reaching the final stage the sequencer would then return to the first stage. The Model 140 Timing Pulse Generator (H. Howe 1967, 21) was designed to deliver voltage pulses that would provide a source of triggers for the various sequencer, envelope generators and sample and hold based modules of the Buchla 100. The timing of the pulses generated could be controlled by an external voltage source and the 1967 Buchla User Manual suggests a circular relationship between the Model 140 and the sequencer modules enabling each step to be of differing length (H. Howe 1967, 22).

The inclusion of these devices, in one of the earliest modular synthesisers demonstrates the purpose and function of these instruments as more than sound generators. Instead emphasising the generation and control of musical events. Morton Subotnick described his compositional techniques using the Buchla 100, where complex rhythms could be generated over long periods of time by combining the various sequencers at odd, differing lengths, or applying voltage from other sources such as envelope generators to adjust the timing of a pulse generator (Vail, 2000, p. 109). The possibilities for the combination and complex interaction of these musical event generating devices, involves a process identical to the creative design of synthesised sounds using the modular synthesiser. It is possible that in the early stages of the emergence of synthesiser instruments, the processes of designing sounds, and generating or manipulating musical events would have been difficult and unnecessary to differentiate.

Curtis Roads offers an analysis of the time scales (Roads 2004, 19) describing 9 sections of scale from infinitesimal (short) to the infinite (long). The description of a continuous spectrum encompassing event frequencies that are understood as sound, through to musical events and structures, resonates with the possibilities encouraged by the modular synthesiser instrument. The sections of the time scale of particular relevance are Macro, Meso, Sound Object and Micro;

> Macro - *The time scale of overall musical architecture or form, measured in minutes or hours, or in extreme cases, days.*
>
> Meso - *Divisions of form. Groupings of sound objects into hierarchies of phrase structures of various sizes, measured in minutes or seconds.*
>
> Sound object - *A basic unit of musical structure, generalizing the traditional concept of note to include complex and mutating sound events on a time scale ranging from a fraction of a second to several seconds.*

Micro - *Sound particles on a time scale that extends down to the threshold of auditory perception (measured in thousandths of a second or milliseconds)*. (Roads 2004, 19)

Subotnick's description of the implementation of an envelope to modulate the timing of a pulse generator that in turn controls the speed of a sequencer effectively shifts the role of the envelope from a *sound object* shaping device, (amplitude, oscillator frequency, filter frequency etc) to the *meso* structural manipulation and production of *sound objects (triggering of sequencer events, modulating phrase tempos, triggering of envelopes etc)*. Modular synthesisers also enable a blurring of purpose and effect from the *sound object* level up to the *micro* where signals become audible. However Buchla made a deliberate design decision to separate audio signals, control voltages and timing pulses (Austin, Kahn, and Gurusinghe 2011, 301), as a result the possibilities for components to transverse from sound object event up to audible frequency or vice versa were reduced. However this is still possible using a Buchla 100 system, for example; a timing generator can operate at high frequencies and in turn trigger a sequencer to modulate an oscillator at an audible frequency to produce complex FM style synthesis.

In contrast to Buchla's approach, the Moog systems approach to control voltage did not differentiate between audio and control signals, enabling many modules to interact with one another (Dalgleish 2016), however different connections were used for gate and trigger sources preventing interconnection with other signals without the use of a converter. The design of the Moog synthesisers was more closely linked to the needs of traditional musician (Pinch and Trocco 2004, 61) and the potential for generative approaches are more limited than those offered by the Buchla equivalent, a point acknowledged by Moog:

There are also people like Morton Subotnick and Suzanne Ciani who are concerned, as Cage was, with production of music as a process, where to realize your music, you would organize a very complex system. The Buchla modular system was designed with this sort of composer in mind more than ours was. It has a lot of capability for triggering sources in sequence, for turning on and off different sources, and for creating a very complex organization of a modular system. You can literally set up a machine that will produce an interesting sounding piece of music by itself. (Hutchins 1974)

Serge Tcherepnin worked with Morton Subotnick in a New York based studio affiliated with New York University in the late 1960s. The studio was centered around a Buchla synthesiser that Subotnick brought with him from San Francisco (B. Gluck 2012, 65, 66). Tcherepnin had worked with electronics since he was a child (Vail 2000, 152) and began to develop circuitry at the New York studio (R. J. Gluck 2009) (B. Gluck 2012, 70). In 1969 Subotnick moved to California Institute of the Arts (CalArts) as Dean of the Music Department ("About Morton Subotnick" n.d.). Tcherepnin also became a Professor there in 1970 (Vail 2000, 149).

Frustrated by the high price of modular synthesiser systems Tcherepnin, worked with Randy Cohen and Richard Gold, to design and built the first 'Serge' synthesiser (initially referred to as 'Tcherepnins') in 1973 (Vail 2000, 149–50). Based on this prototype a further 20 were assembled on the CalArts campus by a coalition of staff, students and 'outside agitators', each participant contributed $700 to cover the cost of materials and after several months each received their own synthesiser (Vail 2000, 150). Tcherepnin left CalArts in 1975 to start the Serge company and continue development of his designs.

The influence of Buchla's approach can be observed in the design of the Serge modular. Specific modules such as the Serge Dual Slope Generator (DSG) are immediately reminiscent of the Buchla equivalent Model 280 (also Models 281 and 284) in that both devices are centred around simple envelopes with adjustable attack and release controls. Tcherepnin's DSG design also enabled the module to act as a voltage processing device capable of 'slewing' the rate of change of an incoming signals' direction either upwards or downwards (Gold, Johansen, and LaPalma 1976, 5–18). This process served much like a low pass filter. In addition, a trigger output was provided to report the end of the envelope's cycle. These design innovations enable the module to be used for a range of other purposes in addition to producing an envelope including; generating subharmonic frequencies from oscillators, envelope following of an external signal, delaying a trigger or gate and acting as a rudimentary audio filter. This flexible approach is typical of Tcherepnin's concept of *patch programmability* (Tcherepnin 1979, 2) where modules can perform a range of distinct functions, this approach reflects Serge's intentions to create cheaper, smaller and more flexible modular synthesisers (Vail 2000, 150).

The Serge modular system does not differentiate between control and audio signals, with the exception of audio output and inputs from outside of the synthesiser system itself (as it otherwise utilises banana plugs with a common ground). Serge oscillators were also designed to continuously sweep from 1hz to 100khz without any range switching (Vail, 2000, p. 151), enabling them to operate across time scales to produce sound object level musical events or audible waveforms. Tcherepnin describes his own interest in electronic music as being a foregrounding of the electronics themselves;

The Buchla's modules made me realise how much more interesting his modules would be, if he had made available to the user the "hidden" sub- functions making up a module. In a sense, dissecting a Buchla module, I could do the same stuff I did with a Japanese transistor radio.

This was the guiding principle of the early Serge: make available electronic functions that are interesting in themselves, though seemingly "un-musical". Thus

modules like the positive slew, negative slew, peak and trough, comparators, processors and wave shapers, etc. came into existence.

(Biddulph et al. 2018, sec. Foreword)

John Cage is quoted as remarking that the Serge synthesiser was "the best musical composition that Serge had ever made" (Holzer 2011), perhaps in jest, but nevertheless acknowledging the generative and compositional nature of these instruments. Serge synthesisers continued to be produced in limited numbers throughout the 1980s, 90s and 00s, sometimes in kit form, many module designs are still available today, manufactured under license by various companies.

The Eurorack modular standard established by Dieter Doepfer in 1995 (Dalgleish 2016) has emerged at the forefront of the more recent resurgence in modular synthesisers. According to the ModularGrid website database there are currently 342 module manufacturers (as of February 2019), and nearly 5600 modules. The legacy of historic modular synthesiser design is apparent in many modules; from licensed manufacturing of older designs to new designs that clearly build upon specific models or concepts. For example the popular Maths module by Make Noise, of which more than 5000 units had been sold by late 2016 (Grosse 2016) draws heavily upon the design of the Serge DSG (also DUSG), adding a two channel invertable mixer and logical OR output inspired by the Buchla Model 257 (Rolando 2009). Through these contemporary designs, compositional approaches and processes have endured and advanced since their origins in the 1960s and 70s.

4. QUALITIES OF MODULAR SYNTHESISER GENERATIVE COMPOSITION

The specific possibilities for composition using a modular synthesiser are endless, the expandable and completely customisable nature of the instrument itself compounds this. However it is still possible to identify some overarching factors that can be generalised to impact upon generative compositional processes in modular synthesis. The following attributes have been subjectively developed through a process of reflection upon my own compositional experiences with modular synthesisers (Schön 1983).

4.1. Creative Constraints

Any modular synthesiser has a limited range and number of modules, this is in contrast to working in software, where aside from any CPU overhead, there is an unlimited number of devices and range of devices[2]. This limitation forces the modular synthesiser composer to problem solve, working with and around limits, compromising and innovating with what is available, and using these constraints to drive creativity (Stokes 2005).

4.2. Limited Iterations and Modules

The limit of available modules to a given synthesiser instrument also has a practical implication for the generative systems that are devised; complex interconnection and greater reliance between devices is encouraged. For example, a low frequency oscillator may have multiple waveform outputs, each affecting a different aspect of the composition, in this case any change to the oscillator frequency will impact the structure in a range of ways.

4.3. Functionality Across Broad Timescales

The continuous scale from audible frequency to compositional structure which the modular synthesiser operates in, foregrounds the underlying function of the module devices as they must be considered in the two contexts of sound and event generation simultaneously. This encourages the composer to think laterally about the possibilities inherent in a device or a configuration of multiple devices. For example, a consideration of the impact that modulating a variable pulse width waveform oscillating at low frequency requires an understanding of the underlying function beyond the audible phenomena of an oscillating pulse waveform.

4.4. Overlapping Embedded Design Philosophies

Modular synthesiser modules function at a higher level than the individual object devices made available in a software context such as MAX or Pure Data, necessarily carrying a greater level of design intention, philosophy and aesthetic preferences. Functioning on a scale somewhere in between a self contained instrument and its separated constituent components, the modular synthesiser musician is operating in a field of overlapping, interconnected (semi) instrument designs. In response to the surge in modular synthesis popularity both Cycling 74 and Native Instruments have developed standardised systems for MAX and Reaktor respectively that enable the design and use of higher level devices that emulate the

[2] Comparisons are often made between between modular synthesisers and patching software such as MAX, Pure Data or Reaktor, the points of similarity are clear in the connecting of signals between discrete objects and modularity of objects. It is unclear which technology established the modular approach first, the computer music pioneer; Max Mathews suggested that the approach was simultaneously developed by himself in the field of computer music and others working with analog electronics (Roads and Mathews 1980, 16). The motivation behind the design decision for Mathews was to create an instrument building environment that did not impose his tastes or ideas upon the musician (Roads & Mathews, 1980, p. 16), contemporary visual programming languages have continued on this trajectory offering an open environment where almost anything seems possible.

modular synthesiser paradigm ("BEAP - Powerful Modules for Max for Live," 2013) ("Reaktor 6 Blocks are like getting a modular in your laptop for $199," 2015).

4.5. Continuous Signal

In learning to use a modular synthesiser after working in a computer based compositional environment, the first conceptual hurdle is often in relation to Voltage Controlled Amplifiers (VCA) and the nature of electrical signals in the modular environment. Modular synthesisers invert the digital and keyboard centred paradigm of the note on, but also broader acoustic instrument paradigms; the plucking or bowing of a string, the striking of a drum and the blowing of a reed or brass instrument, because the electrical signal is always present while the instrument is switched on. A VCA is employed in a modular system not to produce sound, but to prevent it and attenuate it, the modulation of the VCA with an envelope or other control voltage source, allows for a signal to pass through (H. S. Howe 1975). A module must still be patched up in order for its signal to be audible or to have an effect upon other modules, but once a connection is made the signal is continuous. The break in the cause and effect relationship of the musician to the instrument may in turn impact upon the process of composition with a modular synthesiser, where signal flows are connected, attenuated and muted in order to create musical form and structure. Composer and sound designer Suzanne Chiani's description of her experience of the Buchla instruments resonates; "It's a living thing - you feel like it's alive when you're interacting with it" (Friedlander 2017).

5. CONCLUSION AND NEXT STEPS

Generative composition was a key aspect of synthesisers since the development of commercial models in the mid 1960s. This aspect of synthesis was set aside in the evolution of commercial, fixed architecture synthesisers in the early 1970s but continued to be developed through modular synthesisers. The resurgence of interest and commercial viability of modular synthesisers has resurfaced these ideas and made them available to contemporary electronic and experimental music composers.

Further scholarly attention to modular synthesisers in general is needed, the contemporary resurgence of these instruments has opened up a range of possibilities and inquiries that may re-frame experimental and electronic music practices. The research presented in this paper is a first step in exploring the nature and significance of generative compositional approaches enabled by modular synthesisers. Further research is needed to understand the methods and approaches employed by composers and their experiences of the instruments as compositional devices. This should be supported by an in-depth study of key historical and contemporary instruments, and the compositional affordances of significant module designs and configurations. This work may serve to foreground the rich history of analog systems in the compositional domain and to stimulate further creative research in the area of generative composition with modular systems.

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REFEREED CREATIVE WORKS

Jesse Austin-Stewart: BEYOND NEARSIGHTEDNESS (2018)
beyond nearsightedness is an octophonic work that functions as a deconstruction of the relationship between space and gesture.

Leah Barclay: MIGRATION PATTERNS: INVISIBLE ECOSYSTEMS (2018)
'Migration Patterns: Invisible Ecosystems' is a 16-minute surround sound live performance (8 channels). All sounds featured in this piece were recorded with hydrophones in Queensland, Australia.
The ocean is often an invisible ecosystem, a complex acoustic environment, where marine life is reliant on sound to communicate and survive. Sound is felt, reflected and absorbed in aquatic ecosystems. It propagates underwater at different speeds and is affected by temperature, pressure and salinity. The impacts of climate change are often very visible in terrestrial environments, yet dramatic changes in marine ecosystems are going unnoticed simply due to visibility. Increased anthropogenic noise and rising temperatures continue to cause unfathomable ecological disruptions that are dramatically transforming the acoustic ecologies of our oceans.
'Migration Patterns: Invisible Ecosystems' in an immersive performance exploring the fragility and complexity of marine life that live in a world of sound and vibration. Drawing on a large database of hydrophone (underwater) recordings from the coastline of Queensland, this work traces sonic migration patterns and shifting ecologies from the smallest micro-crustaceans to the largest marine mammals on the planet. The recordings focus around the Great Barrier Reef, Great Sandy Biosphere Reserve and K'Gari (Fraser Island), a major transitory point for humpback whales on their southern migration. The whale song continues to adapt and evolve in response to changing environments and the recordings are contributing to ongoing scientific research on the value of aquatic acoustic ecology in climate action.
This performance immerses listeners in the depths of marine ecosystems and transposes infrasonic and ultrasonic recordings into perceptible ranges. The soundscapes are layered and sculpted into an immersive sonic environment that navigates the ocean through auditory data and embodied listening.
The creative development of Migration Patterns has been supported by the Queensland Conservatorium Research Centre and Griffith Climate Change Response Program at Griffith University. Additional hydrophone recordings for this project have been provided by Marine Biologist Elisa Girola at JASCO Applied Sciences.

Ryan Burge: RETURNING HOME (2019)
returning home brings together disparate places captured in field recordings from various locations in Perth, Western Australia. Drawing from the contemporary trends of 'hypnagogic pop' and 'hauntology' that exploit nostalgia through appealing to one's memories of the past through the use of cultural artefacts, the piece combines digital synthesis with sounds recorded using a condenser mic, coil mic and hydrophone. Noah Creshevsky (2005) defines hyperreal music as an "electroacoustic musical language constructed from sounds that are found in our shared environment ('realism'), handled in ways that are somehow exaggerated or excessive ('hyper')", whilst Barry Truax (2012) suggests a possible form of soundscape composition that is the creation of a purely imaginary or virtual world, one that arguably aligns with the concept of the 'hyperreal'. Probing the intersection of these definitions by using familiar found sounds, articulate synthetic gestures, the electromagnetic sound of logging into social media and lo-fi production techniques such as noise, crackle and saturation, returning home explores the possibility of hyperreal music.

Nicole Carroll: ORRERY ARCANA (2018)
The Orrery Arcana system includes a self-made modular hardware controller and custom software that allows the performer to manipulate sound during performance. The hardware controller is used to navigate systems that encompass chance operations, conceptual mapping, and data mapping, to control audio generation and processing. These process systems are based on NASA lunar data, the esoteric system in W. B. Yeats' (1865-1939) A Vision" (1937), and the numerology and symbolism of the Tarot. The NASA data and Yeats' system both relate to moon phases. The NASA data is applied directly to synthesis and processing parameters, while Yeats' system and poetic symbolism are used for compositional and structural shape. NASA and Yeats provide the objective and

subjective binaries that operate independently and collaboratively. W. B. Yeats' system is situated in the centre, as it contains elements of both Tarot and lunar mapping. Virtual Tarot cards are drawn" during the performance, and the numerological assignments and symbolism are mapped to processing parameters as well as macro structures.
Sound sources include generated audio, field recordings that represent elemental correspondences, and samples from the composer's other bespoke instruments. The controller features modular control objects in the form of concentric rings that represent a Tarot deck. The major arcana cards control macro parameters and development trajectories, while the minor arcana cards control selected synthesis and processing parameters. The hardware interface is housed on a planetary gear system, which allows the performer control over timing and sequenced events through manual gear rotations. Each gear is equipped with a sensor plate upon which light, magnetic, and capacitive-touch sensors are mounted; these sensors are manipulated via concentric rings of various colours of acrylic and embedded magnets.

John Robert Ferguson and Andrew Brown: AUDIO-VISUAL INTERIORS (2019)
John Robert Ferguson and Andrew - laptops
Audio-Visual Interiors is a quadraphonic audio-visual composition performed by a live electronic duo. The work explores relatively uncharted territories of timbral and rhythmic space, presenting a sonic landscape that is unfamiliar yet strangely reminiscent. Both authors have developed new bespoke instruments for this work, these utilise Pure Data running on portable mobile devices. Brown explores ring modulation synthesis controlled by multi-dimensional touch gestures; this process provides a rich diversity of sonic potential whilst always maintaining remnants of the physical gestures used in performance. Effects and quadraphonic sound distribution enhance and relocate what is otherwise a simple monophonic sound source. Ferguson uses a self-made instrument that features an array of buttons and knobs wired to an iPhone, resulting in a surprisingly well-ordered assemblage that may nevertheless be liable to melt at any moment. Euclidean rhythms and sound-file granulation are at the foreground of Ferguson's sound world but the audio samples chosen very much speak for themselves, beyond the performers attempt to manipulate them. Touch Designer is used for live visuals, with both performers sending MIDI messages from their mobile devices to a laptop running visuals. Quadraphonic sound diffusion is both automated and responsive to tactile input and computational parameters. The work involves performance with live algorithms where performer agency is augmented by machine agency, as all agents exert their influence in somewhat unpredictable ways. The work emerges from the interactions amongst musicians and machines, following a tight compositional structure that still allows for moment-to-moment improvisation and surprise.

Sandra González: PROYECCIONES SONORAS (2018)
Kim Tan – Flute, Sandra González - Laptop
The work was composed in the research program "Temporal Systems and Spatial Synthesis in Sound Art". To compose the part of the bass flute, the Pitch Class Sets and Combinatorial Matrices were used through the External Object Library PCSlib (Pablo Di Liscia - Pablo Cetta) for Pure Data (Miller Puckette). The investigation of the relationship between the spatiality of sound and the methods of synthesis and transformation of the same was approached from the analytical approach proposed by Gary Kendall. The electronic sounds work the game with the perceptive grouping. Multichannel reverberation is used as a processing technique to create artistic content. We consider the location of the flautist, to work the "Interplay" between the perceptive grouping as a function of spatiality. They also take into account their study of containment as an auditory scheme. The implicative theory specified by Stéphane Roy is developed in the work through disturbing movements that cause disruption.

Barry Hill: THE SOUND OF A SUNRISE... (2019)
This work is a is an automated data sonification and video recording captured at a specific geographic location, time and date (Sunrise January 1st 2019). The recording seeks to be a representation of the environmental energy exchange between human technology and the natural environment using data remotely hacked from a wi-fi data server designed to monitor the performance of a prototype mobile

solar power generator. The stereo soundscape is created using music and data networking software (Raspian Code, MAX 4 Live, Ableton) that continuously measures the amount of sunlight striking the photovoltaic solar panels of the power generator. The system creates a musical 'composition' that is autonomously controlled and manipulated by the patterns of sunlight present in the immediate environment at the time of the recording. The soundscape comprises four distinct melodic voices that represent or sonify energy consumption, production as well as battery storage voltage and capacity data. The audio work is experienced as a polyphonic linear melody that moves through a chromatic chord progression. A synchronised video image accompanies the soundscape that allows the audience to experience the changing visual imagery of the environment during the data sonification recording. The video image is captured from Woodford Folk Festival Hilltop stage looking south east toward the sunrise the across the Sunshine Coast Hinterland. Creative themes imbedded within the work include data sonification, acoustic ecology , computer engineering as art and the age of the anthropocene. The work is inspired by broad themes of environmental awareness, Maddrell's (2010) "polyvocal landscapes" and Turrell's "Sky space" visual art installations.

Fiona Hill: IMAGO (2018)
Dominique Chaseling – Flute, Judith Dodson – Soprano, Fiona Hill - Laptop
"She went hysterical when I was taken away and it took two people to hold her down." "I used to look into prams. I was convinced that I was going to find her." "As for my birth father, I don't know anything other than his name." These are just some of the harrowing quotes from transcripts compiled on the History of Adoption website by Monash University:
http://artsonline.monash.edu.au/historyofadoption/
Forced Adoption, one of the recent tragedies of Australian history, forms the foundation of the work 'Imago': for flute, voice and electronics (also able to be performed as solo flute and electronics). The piece responds to the multi-faceted stories of those affected by Forced Adoption as well as societal attitudes and the eventual governmental apology to victims. The work layers text derived from victim transcripts, interviews and governmental hearings with live, processed flute and voice and music concrete derived from domestic soundscapes. The work is able to be performed in stereo or quadrophonic configurations. It is controlled by a standalone Max MSP application or via a MaxMSP patch. The piece was created with funding from the APRA AMCOS Art Music award and it's premiere was at Tilde~ New Music Festival, Melbourne, Australia on 19th January 2019 with Lamorna Nightingale on flute and Jane Sheldon soprano. Further funding for a recording of the work alongside other current Australian electroacoustic flute pieces has been provided by the Australia Council for the Arts. In addition an educational kit aimed at secondary high school students has been funded by the NSW Department of Education. Through extramusical inspiration Fiona ties together often disparate genres and sound worlds in an electroacoustic and spatialised context. Through the use of technology she experiments in blurring the boundaries between performer and computer attempting to create seamless integration of components and ensure maximum freedom for performers.

David Hirst: THE PORTUGUESE SUITE (8 Channel Version) (2018)
The Portuguese Suite follows on from the piece Imaginação de Viseu (Imaginations of Viseu) which was composed for the project: SONIC EXPLORATIONS OF A RURAL ARCHIVE - Electroacoustic Music and Sound Art International Competition, coordinated by Binaural/Nodar (Portugal). That work used sound sources recorded in the rural region of Viseu Dão Lafões in Portugal. The Portuguese Suite takes some of the sounds from the previous piece and processes them into purely abstract sounds using two suites of tools I developed in 2017 for Max/MSP. The first suite of tools is called NES-Tools, and processes sound in the time domain. The second suite of tools, NES-Spectrale, processes the frequency domain representation, and builds on the work of Jean-François Charles (2011). This version has been especially mixed and mastered for 8 channels using the Ambisonics Toolkit (ATK) from the University of Washington.

Donna Hewitt: PERMAFROST (2019)
Alana Blackburn – recorders, Donna Hewitt - laptop
The work is composed specifically for Blackburn and is the first composer-performer collaboration between these two artists. It is inspired by Alana's comprehensive musical vocabulary with the

recorder family and highlights her extensive performance experience with the instruments. The work utilises both natural and synthesised sounds, including some recordings of Antarctic wildlife. The work aims to entwine the textures, timbres and spatial characters of the live and pre-recorded sounds. The work is inspired by the concept of 'Permafrost', the 'permanently' frozen earth found in colder climates. The predicted thawing of the permafrost is accompanied by some ominous scientific predictions for the future of our climate, ecosystems and health and was at the forefront of Hewitt's mind as she composed this work.

Pei-Fen Huang: IN THE NAME OF LOVE (2018)
Dominique Chaseling – Flute, Pei-Fen Huang - Laptop
This piece of music attempts to make a live flute playing, and a pre-recorded electronic sound, similar but different mutual restraint and counterbalance. Described by music: the emotional entanglement between the two generations with blood relationship; when the protection of the previous generation for the protection, teaching and love envisioned by the next generation, fermentation becomes excessive intervention, limiting the development of the next generation, The generation is obedient to unbearable pressure, and then resists the conflicts that arise.
The flute represents in the music is a life individual that seems to be protected, but is actually not respected, restricted everywhere, and unable to maintain freedom. The original sound material of electronic music comes from the pre-recorded flute and midrange flute, representing a number of carers (elders) from the same blood relationship. In the interaction between flute and electronic music, it can be found that the flute is often restrained by electronic music and conflicts. Although in the music, the flute is very eager to break away from such restraint, and has tried to get rid of the restriction to make a monologue (solo part), Under a lot of pressure, in the end, the flute was gradually engulfed in the sound of a noisy electronic music. The music in the music is spoken in Taiwanese words, "Tia Way, Gon Lee Boon Tan, Wee Lee Ho", etc. These keywords represent the Taiwanese experience of the Japanese rule. The era, the influence of the legacy of military culture, and the national government in education, instilling traditional Chinese Confucianism, and the values of various social concepts, the father's generation to the next generation, claims to be from the language, the language traits.

Stuart James: PARTICLE IV (2019)
Building on a series of works exploring a synergy of live acoustic feedback and spectral spatialisation, often involving the processing of a live instrument, this work builds on two new developments by the composer: the determining of multi-point spatial texture based on the multi-point spatial distributions of frequency spectra and auditory effects across the soundfield, and secondly, an application of video matrix data as a structure for determining frequency distributions across space facilitated via audio-rate controlled ambisonic equivalent panning. The work is a study designed to demonstrate the variety of spatial distributions possible using a variety of sound sources derived from found objects and field recordings. The performance will involve the live diffusion of these sound sources using an interface that allows for controlling the choreography of multi-point spatial distributions, and how these are animated and behave. This work will be adapted for the Meyer Constellation array at Monash University utilising Manifold-Interface Amplitude Panning (MIAP) with Meyers SpaceMap software and the MIAP objects for MaxMSP.

Stefanie Petrik, Kylie Supski and Roger Alsop: LECTURE ON NOTHING (2019)
Stefanie Petrik, Kylie Supski and Roger Alsop - performers
John Cage's original "Lecture on Nothing" focused on music's experiential effects on consciousness expansion. Our adaptation uses spatial sound design & visual projections to disorientate the listener in a unique participatory installation. Moving through the installation's space builds a unique linear narrative. This movement forces the listener to interact with the experiential intimations that John Cage was exploring in 1950. Its 8-channel sound design makes use of memory and independent free-associations. Visual projections including elements of performance and collage techniques also present Cage's original text with a modern visual interpretation.

Julian Scordato: CONSTELLATIONS (2014)

"Constellations" is a composition for IanniX graphical sequencer and electronics. It was created between March and April 2014. The world premiere occurred on October 1, 2014 at the CCRMA (Center for Computer Research in Music and Acoustics) of the Stanford University, in the contest of their annual Transitions concert series. Further performances and screenings took place within numerous international festivals and exhibitions.

Based on the reading of a IanniX score constituted by 356 punctual events and two drones for controlling additive synthesis parameters and bandwidth-limited noise respectively, this work assumes a certain complexity through the interaction between elementary electronic sounds in a feedback network capable of processing them synchronically and diachronically. Thus, sonic elements no longer exist just as intrinsic and independent entities; they become instead strongly characterized by global processes that transform them as part of the network.

Michael Spicer: A FIRESIDE TALE (2019)
Over the past few years, I have been regularly using abstract digital images as graphic musical notation for acoustic and electronic performances. In this context, I'm particularly interested in how the pattern recognition features of our brain can construct narratives from the abstract images and how they that can inform the musical interpretation. This piece is centred on a video score that I created by a combining a sequence of digital images and then processing them in video patcher that I made with vizzie, in MaxMSP. This particular interpretation of the score was made by assembling several recordings of modular analogue and digital synth performances. Whilst working with the score, a vague narrative based on an imaginary "history of the universe" story somehow emerged from the sequence of images. This narrative is reflected in the instrument design and performance decisions.

Cissi Tsang: CORRIDOR (2019)
Corridor is a piece exploring the use of a single sound source to construct a soundscape - as though the sound is mediating on itself. This piece is also about movement, loss and attempting to preserve what was left. The original field recording was made in an underpass in Neerabup National Park, in the northern suburbs of Perth, Western Australia. Neerabup is an important stretch of bush for two main reasons - firstly, it acts as a wildlife corridor for native wildlife (particularly the many native birds) and secondly it incorporates and protects part of an ancient Aboriginal migration route, which is now a walking trail called the Yaberoo Budjara Heritage Trail. The piece was then constructed by overlaying multiple versions of the original recording together, using a mixture of time stretching (by 800%, 400%, 600% and 200%), effects (delay, resonators, doppler) and panning. The resultant composition was then turned into an audio visualisation using Trapcode Sound Keys and Trapcode Form, in Adobe After Effects.

Lindsay Vickery: QAALUP 2019
Lindsay Vickery – bass clarinet
qaalup derives pitch, rhythmic and formal structure from a field recording made in the Fitzgerald River National Park, on the Western Australian coast between Bremer Bay and Hopetoun. The region is the largest single national park in the south-west of Western Australia and a UNESCO designated biosphere – one of only 10 in Australia and the only one in the state. It is estimated to support 12 threatened fauna and 39 threatened flora species, and contains about 20 per cent of WA's described plant species, many of which are found nowhere else in the world. Quaalup, a homestead built in 1858 is the only property in the park. A field recording was pitch-shifted down by two octaves and then audio outside "ecological niches" (frequency bands with greater activity) at 1231, 505, 115, and 68Hz, was threshed out to create multiple channels of sound. Strangely this process resulted in the creation of a "found object" bass-line (something like Robert Ashley's Automatic Writing (1979)). A temporally proportional score was built from data in the spectrograms of each channel. The score is performed from iPad using the Decibel Scoreplayer with 5 additional iPads used to generate synchronised audio diffused through Bluetooth speakers.

Alex White and Ian Stevenson: MESO-MODULUS, FOR MODULAR SYNTHESISER AND DIGITAL SPATIALIZATION (2019)

This 12 minute creative performance work for modular synthesiser and digital spatialisation explores the compositional affordances of the modular synthesiser in the context of live semi-improvised performance. The proposed performance relates to a long paper submission to ACMA 2019 Analog Algorithms: Generative Composition in Modular Synthesis and would function as a demonstration of the concepts explored relating to generative compositional processes specific to modular synthesisers. The work plays with the tension between fluid gestural morphologies and meso-scale forms of sonic repetition and pattern formation. Temporal form is developed through self-quotation enabled by the storage and recall capacities of the spatialisation system. A distanced-based algorithmic panning system creates both immersion and a sense of soloist and ensemble structure.