PORTFOLIO OF COMPOSITIONS

by

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Abstract

This portfolio of compositions comprises acoustic, electronic and mixed works. Particular focus is given to examining the compositional process, with each piece exploring a contrasting approach. Key themes include the degree of composer autonomy and approaches to generating material. Indeterminacy, tuning, concepts of time and live electronic processes are primary concerns within a broadly experimental aesthetic.

ACKNOWLEDGEMENTS

I would like to thank my supervisors, Scott Wilson and Daria Kwiatkowska for their guidance, and my wife Hannah for her patience and support.

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MEDIA CONTENTS

The contents of the attached USB stick are specified below:

shimmer.wav *Shimmer* audio - James Opstad (double bass)

shimmer.pdf *Shimmer* score

shimmer.scd *Shimmer* SuperCollider code

shades.wav *Shades* audio - Birmingham Contemporary Music Group

shades.pdf *Shades* score

glyptic.wav *Glyptic* audio (playback requires 8-channel ring of speakers grouped in stereo pairs)

glypticStereo.wav *Glyptic* audio - stereo mix

glyptic.scd *Glyptic* SuperCollider code

veil.wav *Veil* audio - Angharad Davies (violin)

veil.pdf *Veil* score

veil.scd *Veil* SuperCollider code

commentary.pdf Commentary

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LIST OF DEFINITIONS

Auditory masking when the perception of one sound is affected by the presence of another sound.

Brownian motion a continuous-time stochastic process, also known as the Wiener process. Can be approximated by a random walk.

Critical band the band of audio frequencies within which a second tone will interfere with the perception of the first tone by auditory masking.

Finite State Machine an abstract machine that can be in exactly one of a finite number of states at any given time.

Just intonation a musical tuning in which the frequencies of notes are related by ratios of small whole numbers.

Linearity principle of composition and of listening under which events are understood as outgrowths or consequences of earlier events.[1]

Markov chain a stochastic model describing a sequence of possible events in which the probability of each event depends only on the state attained in the previous event.

Mid-Side technique coincident microphone technique using a cardioid or omnidirectional middle microphone and figure of 8 side microphone to create an encoded stereo image.

[1] Jonathan D. Kramer. *The Time of Music.* Schirmer Books, 1988, p. 453.

Modes of Limited Transpositions collection of symmetrical scales compiled by Olivier Messiaen.

Moment self-contained (quasi-)independent section, set off from other sections by discontinuities.[2]

Moment form a mosaic of moments.[3]

Network MIDI a protocol to transport MIDI messages over Ethernet and WiFi networks.

Nonlinearity principle of composition and of listening in which events are understood as outgrowths of general principles that govern entire pieces.[4]

Psychoacoustics the scientific study of sound perception.

Random walk a stochastic process that describes a path that consists of a succession of random steps on some mathematical space such as the integers.

Stochastic randomly determined.

SuperCollider a platform for audio synthesis and algorithmic composition.

Vertical time temporal continuum of the unchanging, in which there are no separate events and in which everything seems part of an eternal present.[5]

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[2]Kramer, *The Time of Music*, p. 454.
[3]Kramer, *The Time of Music*, p. 454.
[4]Kramer, *The Time of Music*, p. 453.
[5]Kramer, *The Time of Music*, p. 454.

1 INTRODUCTION

1.1 WORKS AND CONTEXT

This commentary accompanies a portfolio of four works composed in 2016-17. The initial focus of my research was the combination of acoustic instruments, particularly strings, and live electronics. As I progressed, however, I found myself increasingly drawn to the compositional process itself as a topic of investigation. In writing these works I therefore sought to examine a variety of compositional approaches in a self-reflective and experiential manner. These approaches strongly relate to themes embedded in experimental music practice, including indeterminacy, nonsubjectivity and concepts of time. Technology continued to play a key role and I used SuperCollider in the creation and realisation of three of the works.

Shimmer is an indeterminate composition for double bass and sine waves, with pitch material derived from natural harmonics on adjacent strings. The double bass part is presented to the performer by an iPad score viewer with pages selected according to a logical process.

Shades was written for the Birmingham Contemporary Music Group for an ensemble comprising Flute, Oboe, Horn, Percussion, Harp, Violin, Viola and Cello. The piece sought to combine a process oriented approach to generating material with an intuitive approach to drawing upon it.

Glyptic is an 8-channel fixed electroacoustic composition. All the material is derived from recordings of the tuning of a church bell made at the Whitechapel Bell Foundry. From this, I chose to create a large mass of sound material using a process implemented in SuperCollider. I then carved the piece from this material, much as a sculptor might carve stone.

Veil for soloist and live electronics is an indeterminate composition which makes use of live sampling and frequency analysis. The score takes the form of a flowchart and the performer interacts with the computer via a bluetooth foot switch. The piece is informed by the psychoacoustic theory of critical bands.

1.2 THE COMPOSITIONAL PROCESS

While the composition of each piece employed a distinct approach, there are also overriding themes which influenced the methodology. I was interested in experimenting with varying degrees of composer autonomy and creating a certain distance between myself and the material. This idea of distance, which can be characterised as nonsubjectivity, is often viewed as a distinguishing feature of experimental music. In *Experimental Music Since 1970*, Jennie Gottschalk writes:

> One of the points that initially seems most contradictory is that in order for a listener to have a rich, subjective, differentiated experience, a composer of experimental music often feels a necessity to remove her own subjectivity–tastes, associations, discernment,

> emotions–as much as possible from the process of making the work.[6]

The composer Christopher Fox has also suggested that a characteristically experimental approach includes the:

> 'distancing of creative will from created sound' and the rejection of the 'possibility of music as a direct and immediate outpouring of the creative will'.[7]

It is important in this context to recognise the impossibility of a purely nonsubjective approach to composition. Even works composed using chance procedures require choices to be made by the composer which inevitably reflect their stylistic preferences. This does not, however, negate the value of incorporating a greater degree of nonsubjectivity and it is this balance that I wished to explore. This primarily involved the use of process oriented methods for generating material which could then be drawn upon in a variety of ways. Discussion of these compositional strategies is discussed in detail within the context of each work.

1.3 CONCEPTS OF TIME

The power of music to shape our experience of time has become one of my key compositional concerns. My interest in this area was prompted by my own

[6] Jennie Gottschalk. *Experimental Music Since 1970*. Bloomsbury Academic, 2016, p. 3.

[7] Christopher Fox. "Why Experimental? Why me?" In: *The Ashgate Research Companion to Experimental Music*. Ed. by James Saunders. Ashgate, 2009, p. 8.

listening experiences, particularly with regard to Morton Feldman's music. My thinking on the subject has been further informed by Jonathan Kramer's book, *The Time of Music*. Terminology from this text is used in discussion of the works and has been included in the List of Definitions. As Kramer writes, "musical time is both linear *and* nonlinear", and, as time is not bound by the law of contradiction, "Opposing characterisations are not mutually exclusive".[8] All music exhibits properties of linearity and nonlinearity but it is the balance of these forces that defines our subjective experiences. I wished to explore this balance in the included works, much as I was exploring the relationship between subjectivity and nonsubjectivity in the compositional process. This forms an important parallel as, in both cases, all music exhibits qualities of each, but music in the West has traditionally shown a significant bias. Tonal progression is a distinctly linear force while the prevailing romantic conception of the 'genius' composer and composition as an emotional outpouring of the 'self' is highly subjective. My own preference has been to promote aspects of nonlinearity and to attempt to conjure a range of temporal experiences. Like Kramer, I believe, "Deep listening allows us to transcend the time the piece takes and enter the time it evokes."[9]

Deep Listening is a practice created by the composer Pauline Oliveros. It is a form of meditation that aims to expand the perception of sound. In her own words:

> The practice is intended to expand consciousness to the whole

[8]Kramer, *The Time of Music*, p. 2.
[9]Kramer, *The Time of Music*, p. 7.

> space/time continuum of sound/silences.[10]

Oliveros here draws attention to the dualities of space/time and sound/silence. These interrelated concepts have been central to my compositional thought and the juxtaposition of sound and silence is a key feature of the included works. This serves both to frame events and to create separation. Iannis Xenakis argued that separation (or discontinuity) is essential to our perception of time:

> Thanks to separability, these events can be assimilated to *landmark points* in the flux of time, points which are instantaneously hauled up outside of time because of their trace in our memory.[11]

He goes on to expand on this interdependency of time perception and memory:

> We see to what extent music is everywhere steeped in time: *(a)* time in the form of the impalpable flux or *(b)* time in its frozen form, outside time, made possible by memory.[12]

This frozen time is embodied in the processes that underpin the works. In *Shimmer*, for example, the indeterminate ordering of events is encapsulated within a Finite State Machine. Our recollections are imperfect however; our

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[10] Pauline Oliveros. *Deep Listening: A Composer's Sound Practice.* iUniverse, 2005, p. xxiv.

[11] Iannis Xenakis. *Formalized Music: Thoughts and Mathematics in Music.* Pendragon Press, 1992, p. 264.

[12] Xenakis, *Formalized Music: Thoughts and Mathematics in Music*, p. 266.

memories dislocated by the long durations and silences. By manipulating memory we also manipulate time.

The relationship between time and space, also central to Deep Listening, is more complex to unravel. Salomé Voegelin believes that sound challenges the possibility of their separation and chooses to bring them together in the concept of *timespace*:

> Sound prompts a re-thinking of temporality *and* spatiality vis-à-vis each other and invites the experience of ephemeral stability and fixed fluidity.[13]

These elusive qualities are what I search for in my music. Perhaps they are most evident in the defined sections of *Glyptic*, outwardly static but bubbling with inner change.

1.4 APPROACHES TO NOTATION

The three pieces involving performers each took a distinct approach to notation. These approaches developed in response to the demands of the piece, often as a result of several revisions. Much as the balance of control was considered in the compositional process, here the hierarchy of composer, performer and technology was frequently evaluated. For example, while indeterminacy was central to both *Shimmer* and *Veil*, the ordering of events was controlled by the computer and the performer respectively. The flowchart notation of *Veil* gives the performer considerable freedom while remaining

[13] Salomé Voegelin. *Listening to Noise and Silence: Towards a Philosophy of Sound Art.* Bloomsbury, 2010, p. 124.

within strict bounds. In all the works I am interested in the score, not as a self-contained entity, but for the relationship it provokes with the performer. This dialogue and the ensuing sonic result remain paramount. My thoughts echo those of Bryn Harrison:

> Perhaps I have a certain mistrust in the notion that the composer can, in some ways, control the experience itself. The experience, for me, is what results from the active and mutual engagement between the composer, performer and listener.[14]

While *Shades* is in some respects the most conventionally notated of the pieces, the frequent changes of tempo and metre offer a unique challenge to the performers. Though aware that these changes would be inaudible to the listener, I felt that they would bring a focus and intensity to the performance that may otherwise be absent. This is an example of using notation to impact upon the psychology of performance and create a particular ensemble dynamic.

1.5 USE OF TECHNOLOGY

Technology plays a prominent role in my work and three of the pieces involved developing programs in SuperCollider. My use of technology broadly falls into two categories. The first is the generation and transformation of sounds. The second is the incorporation of structural indeterminacy, which can include algorithmic processes and performer interaction.

[14] James Saunders. *The Ashgate Research Companion to Experimental Music.* Ashgate, 2009, p. 291.

Despite having invested a great deal of time in exploring advanced techniques for manipulating sound, I have found myself increasingly drawn to simpler processes. Particularly when working with acoustic instruments, I feel that many techniques exert their own character more than I would like. Greater familiarity with these techniques has also made them easily identifiable. This sentiment is shared by Bernhard Gunter:

> I generally stay away from treatments like granular synthesis, morphing and frequency, phase or ring modulation because they appear too 'evident' to me, meaning that they are too easily identified by the listener.[15]

In many ways, it was these reservations that led me to write *Glyptic*, a fixed electroacoustic work. I felt the need to make sound the entirety of my focus without other compositional and performance factors muddying the waters. Inspired by Gunter's own works, I restricted myself to filtering and manipulation of playback speed and position. I built on this experience in *Veil* by automating some of these procedures in combination with live sampling and frequency analysis. At the heart of this thinking is a desire to reveal what is hidden within existing sounds rather than imparting a new identity upon them.

The incorporation of structural indeterminacy has taken several forms. In *Shimmer*, the performer reads from an iPad score viewer with page order and durations controlled by a logical process. In *Veil*, the performer interacts

[15]Saunders, *The Ashgate Research Companion to Experimental Music*, p. 276.

with the computer via a bluetooth foot pedal. To a large extent, the form of *Glyptic* was determined by the Brownian motion which generated the source material. These are all examples of the way in which I have used technology to influence the large scale structure of a work.

2 SHIMMER

2.1 INTRODUCTION

In writing this piece, I was keen to draw on my experience as a double bass player and my knowledge of the instrument. I focused on the harmonic series and adopted an investigative approach, allowing compositional decisions to emerge as a result of the search for patterns.

2.2 THE DOUBLE BASS PART

While all bowed string instruments are capable of producing a range of natural harmonics, the double bass is particularly suited to exploring the harmonic series. The low fundamentals of the open strings and the long string length afford a greater degree of accuracy in reaching higher partials. This is something that has become a key feature of my own work as a double bass player, both as an improviser and performer of contemporary works. A particular influence in this regard is Stefano Scodanibbio whose pioneering work did much to expand awareness of the possibilities of the instrument.

> It is Scodanibbio's conviction that the attempt "to allow the contrabass to sing with its own voice "can only succeed" with the help of a newly invented use of harmonic overtones, which, unlike those of any other instrument, sound just as good or even better

than the normal tones."[16]

The double bass is conventionally tuned in fourths to the pitches E, A, D, G. If tuned in just intonation this makes the ratio between adjacent strings 3:4. The lowest integer relationship between all four strings is therefore 27:36:48:64. In writing this piece I wanted all four strings to inhabit the same harmonic series. It is evident that in conventional tuning this would only result in very high partials of an extremely low fundamental (if the A string is taken as 55Hz then the fundamental would be 55Hz/36 or 1.58Hz). I therefore experimented with tuning the open strings to low partials of the harmonic series. In doing so, careful consideration was given to string tension and its impact on bridge stability and resonance. The minimum necessary retuning was favoured and the tuning I settled on was D:A:D:F♯ which is the ratios 2:3:4:5. This kept the inside strings at their original pitch. The four strings and all their harmonics could now be considered as overtones of a single imagined fundamental with the frequency 18.33Hz (55Hz/3). This is shown in Figure 1. I decided to limit myself to the first nine partials to keep the pitches within a comfortable playing range. While it is possible to play up to the sixteenth partial and beyond on the double bass, moving accurately between them becomes very challenging. With this as my starting point, my next step was to search for patterns in the relationships of pitches on adjacent strings. I located the unisons and the dyads which surround them, as can be seen in Figure 2. This led me to restrict myself to a smaller area on the

[16] Wolfgang Korb. *CD sleeve notes for Stefano Scodanibbio Geografia Amorosa.* Trans. by Steven Lindberg. Col Legno, 2000.

top three strings which I found particularly interesting for its symmetrical properties. This area, shown in Figure 3, suggested pathways between the dyads that could form the basis of an indeterminate process. The unisons shared a note across the strings with another dyad and I decided they could therefore act as a pivot between strings. I began to imagine the unisons as exerting a gravitational pull on the surrounding dyads and devised a logical system for moving between pitches. This is illustrated in Figure 4 and was implemented in SuperCollider in the form of a Finite State Machine. The notation used for the double bass part is significant. As the nodes for any individual harmonic are found by dividing the string equally by the partial number, all above the second partial can be played in multiple positions. I therefore devised a notational system whereby only the string and partial number are stipulated in order to provide flexibility to the performer. This proved to be a clear and succinct form of notation. The score is presented to the performer using an iPad score viewer with page turning and selection controlled by SuperCollider and communicated via Network MIDI.

2.3 THE ELECTRONIC PART

In devising the electronic part for this work, a wide variety of sound generating and processing techniques were explored. These included granulation of samples taken from the double bass and FFT processes. All of these were eventually rejected however in favour of a much simpler concept using sine wave generators. I came to feel that the more complex procedures distracted from the essence of the piece and the unique character of each microtonal

D	**A**	**D**	**F♯**
2	3	4	5
4	6	8	10
6	9	12	15
8	12	16	20
10	15	20	25
12	18	24	30
14	21	28	35
16	24	32	40
18	27	36	45

Figure 1: Natural harmonics of each open string up to the 9th partial.

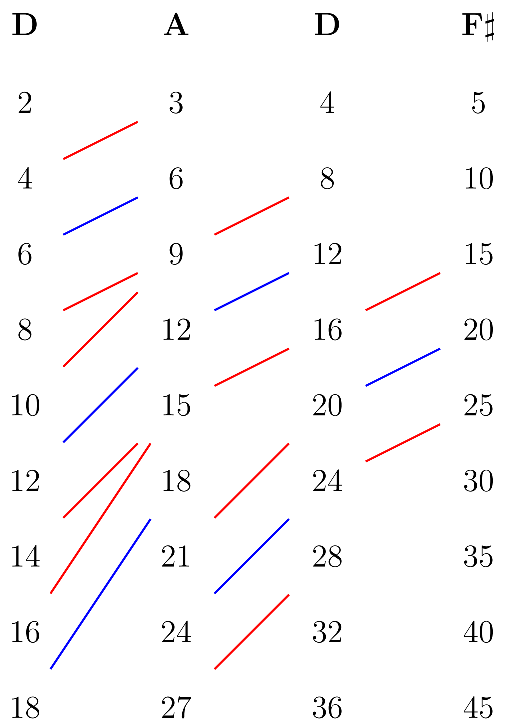


Figure 2: Unisons (blue) and dyads (red).

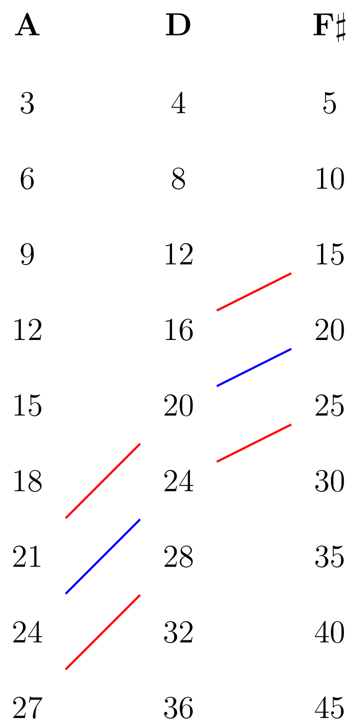


Figure 3: Pitches for the double bass part. Unisons (blue) and dyads (red).

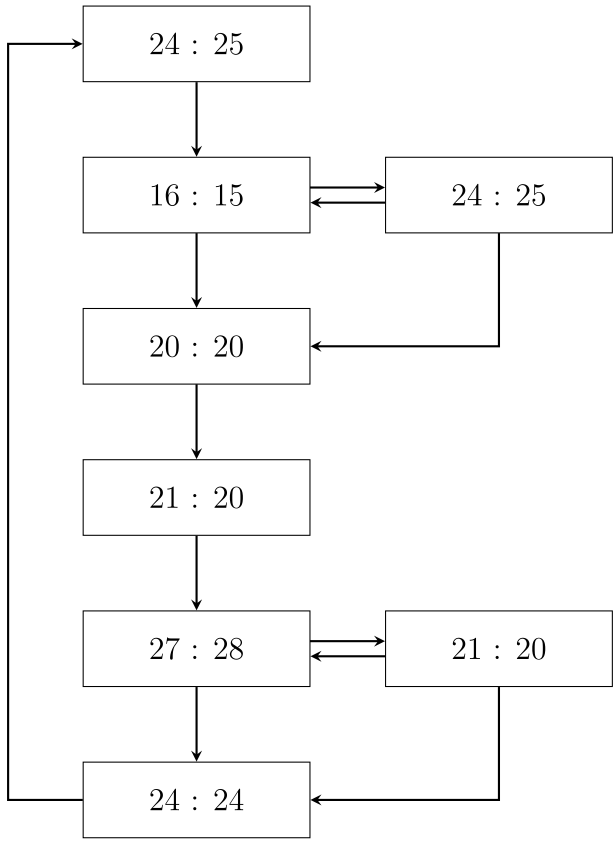


Figure 4: The logical process. Numbers indicate frequency ratios.

interval. I was also attracted to the juxtaposition of the 'perfect' realisation of intervals in sine waves with the inevitably 'compromised' realisation on a real string instrument. This can be seen as philosophically related to Plato's Theory of Forms with the sine waves forming an idealised parallel to the double bass part. For me, the presence of the sine waves draws attention to the imperfections of the double bass performance and focuses the listener on the microdetail within. The combination of acoustic instruments and sine waves has several precedents. Perhaps most significant are a number of works by Alvin Lucier, including *In Memoriam Jon Higgins*, *Septet for Three Winds* and *Crossings*, which explore interference phenomena[17]. More recently, Chiyoko Szlavnics has made extensive use of this combination:

> ...the way different instruments' timbres and spectra interact with each other, as well as with sinewaves, is incredibly rich. When I only use sinewaves you don't have that richness; there is so much more interaction that happens with instruments.[18]

I decided that I wanted the sine wave part to follow the same logical process as the double bass but with a different set of pitches. I therefore returned to my charts and, unhindered by practical considerations, added harmonics based on the fundamental and beyond the ninth partial. This allowed me to use the unisons an octave lower than those in the bass part and form a symmetry between the two. The dyads surrounding these unisons

[17] Alvin Lucier. *CD sleeve notes for Alvin Lucier Crossings.* Lovely Music, 1989.

[18] Simon Reynell. "Chiyoko Szlavnics interview". In: *Canadian Composers Series.* Another Timbre, 2017, p. 64.

create four additional intervals bringing the total number of unique intervals to eight. The pitches for both parts are shown together in Figure 5. The lower limit of the sine wave part is 9:8 which is the interval between tonic and supertonic in five-limit just intonation and an example of a just tone. The lower limit of the double bass part is 16:15 which is the interval between tonic and leading-note and an example of a just semitone. The sine wave part can therefore be viewed as an exploration of intervals between a tone and a semitone in size while the double bass explores the microtonal world of intervals smaller than a semitone. It is also notable that the highest sine wave pitch and lowest double bass pitch are the same, allowing the two parts the possibility of contact.

2.4 REFLECTIONS

In many ways, this piece was an experiment in how far I could push non-subjectivity in my writing. By allowing process and material to inform the decision making, they began to form a reciprocal, interlocking relationship which took me to new and interesting places. I do not deny the subjective decisions I took along the way, but the compositional process definitely had a different feel to my previous work. I set out with the idea of investigating the harmonic series on the double bass and treated it as an 'experiment' in quite a literal sense. This approach was, to a large extent, inspired by James Tenney. As Bob Gilmore has said:

> Tenney believed that "experimental" in music should mean more or less what it does in the sciences. The composer would write a

D	**D**	**A**	**D**	**F♯**
1	2	3	4	5
2	4	6	8	10
3	6	9	12	15
4	8	12	16	20
5	10	15	20	25
6	12	18	24	30
7	14	21	28	35
8	16	24	32	40
9	18	27	36	45
10	20	30	40	50
11	22	33	44	55

Figure 5: Pitches for both parts. Unisons (blue) and dyads (red).

> piece of music, try certain things out, and judge if they worked, didn't work, or only partly worked.[19]

The sense of relinquishing control extended beyond the compositional process to include the performance. The computer-controlled score presentation allowed me to detach myself from any decision making and focus deeply on the sound and feel of the instrument. With no requirement to keep time I could occupy the temporal world of the piece. This temporal world was my attempt at approaching what Jonathan Kramer calls vertical time. The logical process governing the piece creates an endless cycle, devoid of beginning or end. It is at the extreme of nonlinearity with events coming and going but little sense of change. As Kramer says:

> A vertically conceived piece defines its bounded sound-world early in its performance and stays within the limits it chooses.[20]

I believe that this approach allows sound to become the object of contemplation and offers the listener a choice as to whether they engage fully in the act of listening. I hope to capture something of what Alvin Lucier experienced when hearing *KOAN for String Quartet* by James Tenney:

> I could hear the small things that were happening in the music. Once you accepted the fact that it wasn't going to change, and there was no story, no climax, you began to hear the acoustical phenomena.[21]

[19] Darla Crispin. *Artistic Experimentation in Music: An Anthology.* Leuven University Press, 2014, p. 26.
[20] Kramer, *The Time of Music*, p. 55.
[21] Alvin Lucier. *Music 109.* Wesleyan University Press, 2012, p. 194.

3 SHADES

3.1 INTRODUCTION

This piece was written for a workshop given by the Birmingham Contemporary Music Group at the University of Birmingham. I was keen to write an all acoustic ensemble piece and wanted to further explore the idea of creating distance between composer and material. I therefore developed a pool of pitch content and rhythmic structures that I could draw upon intuitively.

3.2 PITCH MATERIAL

The fundamental pitch cell was conceived in five-limit just intonation and is shown in Figure 6. Octave transposition of the G produces the cell shown in Figure 7. This cell can be found amongst the pitch material used in *Shimmer* and comprises a central pitch symmetrically surrounded by two small interval dyads (in this case, two instances of a just semitone). When translated into equal temperament, it comprises a central pitch asymmetrically surrounded by two equal tempered semitones. I decided to limit myself to the semitones as pitch material but continued to use the central pitch to conceptualise a transpositional process. After much experimentation, I created two simultaneous cycles proceeding in opposite directions, as shown in Figure 8. The two cycles form an exact mirror image of each other with the central pitches passing through all twelve notes of the chromatic scale. These twelve permutations are divided into four sections which correspond with rehearsal marks A, B, C and D in the score. In each section, the central pitches form an

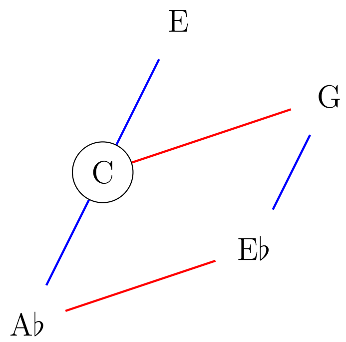


Figure 6: Pitch cell (lattice). Perfect 5ths (red) and major 3rds (blue).

augmented triad with each transposition maintaining one semitone from the last. The combined pitches of the three transpositions form an augmented scale, a symmetrical six note pitch collection. By combining both cycles, each section therefore combines two augmented scales to form a larger nine note pitch set. This pitch collection is what Messiaen refers to as the Third Mode of Limited Transpositions[22]. Two of the four possible transpositions are used in the piece as section D is a reflection of section A, while section C is a reflection of section B. A shift of a minor third takes each cycle to the next section.

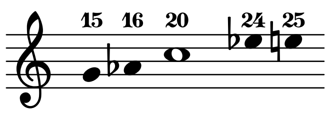


Figure 7: Pitch cell (notation). Numbers indicate frequency ratios.

A conscious decision was made to limit the pitch material to semitones and their inversions, major sevenths. These were treated as pitch classes

[22] Olivier Messiaen. *The Technique Of My Musical Language*. Alphonse Leduc, 1944, p. 90.

and could therefore appear in any octave. These pitches (shown within the square brackets in Figure 8) always appear together rather than singularly. I felt that this uniformity was essential to the process and would focus the ear on the unique timbre of each instrumental pairing. When combined with other pitch pairs, a broad range of intervals are created. The ordering of the dyads is also significant. When combined into larger chords, the dyad in Cycle 2 must be higher in pitch than the corresponding dyad in Cycle 1. This limitation creates a clear distinction between the pitch material in sections A and D and sections B and C despite them sharing the same overall pitch collections.

3.3 RHYTHMIC FRAMEWORK

Having developed a clear harmonic structure for the piece, I sought to create a rhythmic framework within which I could work. As with the pitch material, the focus was on building resources that I could draw upon intuitively. I wanted the piece to be slow, sparse and irregular and was aware that, as such, it would be perceived as arhythmic. Within this context, the question arises of what the bar line represents. In this regard I have been heavily influenced by the music and writings of Morton Feldman:

> Rugs have prompted me in my recent music to think of a disproportionate symmetry, in which a symmetrically staggered rhythmic series is used: 4:3, 6:5, 8:7 etc., as the point of departure. For my purpose, it "contains" my material more within the met-

	Cycle 1			**Cycle 2**		
	C -	[G, A♭]	[E♭, E]	G -	[B♭, B]	[D, E♭]
A	A♭ -	[E♭, E]	[B, C]	B -	[D, E♭]	[F♯, G]
	E -	[B, C]	[G, A♭]	E♭ -	[F♯, G]	[B♭, B]
	D♭ -	[A♭, A]	[E, F]	F♯ -	[A, B♭]	[D♭, D]
B	A -	[E, F]	[C D♭]	B♭ -	[D♭, D]	[F, F♯]
	F -	[C, D♭]	[A♭, A]	D -	[F, F♯]	[A, B♭]
	D -	[A, B♭]	[F, F♯]	F -	[A♭, A]	[C, D♭]
C	B♭ -	[F, F♯]	[D♭, D]	A -	[C, D♭]	[E, F]
	F♯ -	[D♭, D]	[A, B♭]	D♭ -	[E, F]	[A♭, A]
	E♭ -	[B♭, B]	[F♯, G]	E -	[G, A♭]	[B, C]
D	B -	[F♯, G]	[D, E♭]	A♭ -	[B, C]	[E♭, E]
	G -	[D, E♭]	[B♭, B]	C -	[E♭, E]	[G, A♭]

Figure 8: Pitch cell transpositions.

ric frame of the measure.[23]

This idea of the bar as a container for musical material is significant and has been echoed more recently by Bryn Harrison:

> With music that is largely non-directional in nature, and therefore without reliance on musical stresses and downbeats, it is possible to adopt an approach to spatial organisation in which the bar line no longer serves its more traditional time keeping function. Instead, one might view a measure not as a unit of emphasis but as a designated space of a particular size in which to 'contain' musical material.[24]

It was with these thoughts in mind that I devised a rhythmic scheme enabling the pulse to change from bar to bar. My original five note pitch cell (Figure 7) was used to create the proportions. By splitting the cell into two major triads, C and A♭ , I could reduce the ratios by the highest common factors (five and four respectively). 15:20:25 therefore became 3:4:5 while 16:20:24 became 4:5:6. In rhythmic form these could then be expressed as tuplets, as in Figure 9, with the same underlying pulse. I now had six unique bar structures within which I could 'contain' my material. Tuplet notation was used in the initial stages of writing the piece and had the advantage of making the compositional intent and rhythmic relationships

[23] Morton Feldman. "Crippled Symmetry". In: *Essays*. Ed. by Walter Zimmermann. Beginner Press, 1981, p. 124.

[24] Bryn Harrison. "Cyclical Structures and the Organisation of Time". University of Huddersfield, 2007.

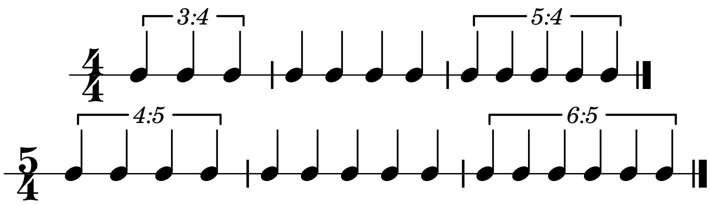


Figure 9: Rhythmic framework (tuplets).

very clear. However, as I wanted the tuplets rather than the time signature to signify the pulse, it was deemed an impractical approach for a conducted ensemble. I therefore fixed the fundamental tempo at ♩ = 60 and translated the rhythmic scheme in Figure 9 into tempo changes, as shown in Figure 10. The relationship between the tempos is clarified in the performance notes prefacing the score.

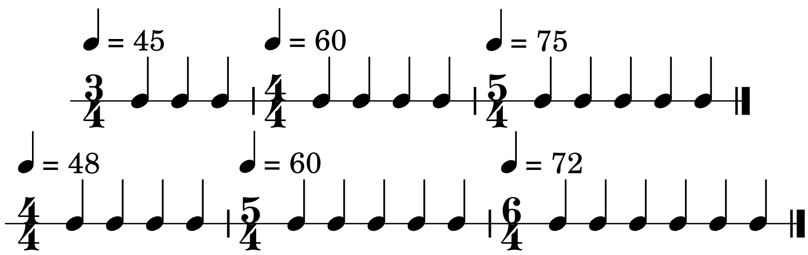


Figure 10: Rhythmic framework (metronome markings).

3.4 WRITING

With so much predetermined prior to committing a note to the page, one might expect the act of writing to feel constricted. In practice however, I found the opposite to be true. The restrictions enabled me to maintain an intense focus on register, orchestration and the placement of musical objects in time. I was able to thoroughly explore the available options at each given moment before making informed choices. Further limitations emerged as defining characteristics of the piece: all the writing is homophonic, the dynamic is quiet throughout and there are no discernible phrases or melodic statements. These decisions were born out of a desire to approach a more vertical sense of time and subvert any sense of linear development. As in *Shimmer*, I defined my bounded sound world early and remained within these bounds for the duration of the piece. The consistently low dynamic demands an intense focus, both of performer and listener. As Bryn Harrison writes:

> In all music which inhabits a quiet sound world, such as Feldman's, the sounds are no longer projected towards the spectator. Thus the listener is forced to bring something of themselves to the listening experience, to meet the sounds half-way and thus intensify the experience.[25]

This intensity is amplified by the frequent use of silence.

3.5 REFLECTIONS

I learnt a great deal from the writing of this piece and the resulting workshop. I built on ideas explored in *Shimmer* within a markedly different context and feel that it was a thorough investigation of the idea that "compositional processes could mediate the relationship between creative intention and musical material."[26] The frequent tempo changes worked well in practice and, by making the rhythmic complexity the responsibility of the conductor, made

[25] Harrison, "Cyclical Structures and the Organisation of Time".
[26] Fox, "Why Experimental? Why me?", p. 25.

matters of ensemble coordination relatively straightforward. The main focus of the rehearsal was the balance of the ensemble. This revealed the complex web of relationships implicit in a single dynamic marking. I was keen for the ensemble to achieve a homogeneous blend at all times which is particularly demanding within a mixed ensemble such as this. It is generally possible, for example, to play much quieter on a string instrument than a wind instrument. The relative dynamic of each performer was therefore determined by a number of contingent factors, including the orchestration at each given moment and the acoustic of the room. When successfully achieved, this allowed the homophonic writing to emerge as a series of composites, a network of timbres distinct from their constituent parts.

4 GLYPTIC

4.1 INTRODUCTION

In writing this piece, I wanted to create a work in which the electronic transformation of sound was my primary focus. This was prompted by my own reservations about techniques I had used in the past and a desire to explore simpler processes in greater depth. It was also an opportunity to apply conceptual themes common to the previous works within the context of a fixed electroacoustic composition.

4.2 BUILDING MATERIAL

The source material for this piece was a recording of the tuning of a church bell made at the Whitechapel Bell Foundry. The tuning process involved filing, grinding on a lathe and striking the bell to determine the pitch content. When this was complete, I also recorded some additional strikes to capture the full decay. I used the Mid-Side microphone technique for maximum flexibility in post-production. Upon listening back, I split the recording into discrete sections which I grouped into categories based on likeness.

In creating this work, I wished to restrict myself to core electronic processes. I felt this would offer an important challenge and enable me to engage more deeply with the source material. I had also begun to share Bernhard Gunter's feeling that many more esoteric electronic processes appear too 'evident' to the listener. This led me to examine Gunter's own methods:

> My main strategy is to transpose samples, then listen to them to find out which of their sonic properties have changed, or become more apparent, and to then 'underline' or 'highlight' these new aspects by means of equalisation.[27]

It became clear, through the manual exploration of these techniques, that my source recordings contained a wealth of inner material. I was keen, however, to further develop the ideas of process and detachment intrinsic to both *Shimmer* and *Shades*. I therefore set about creating an automated process which would weave my source recordings into a larger mass of material. This was implemented in SuperCollider in the form of a Markov chain. An initial segment of sound is selected with the start position and duration randomly generated within defined bounds. The playback direction is then randomly chosen before a check is carried out to determine whether there is enough space in the sound file. If this proves negative, the direction is reversed. The amplitude of the segment is controlled by an Attack-Sustain-Release envelope with the constituent durations randomly generated within specified proportions. For each subsequent segment, the start position is determined by the previous end position, while the attack duration is determined by the previous release duration. The total duration, direction and release are determined as previously. This creates a seamless overlap between segments with the process creating a continuous random walk around the sound file. This kind of movement is often referred to as Brownian motion and satisfies the Markov property whereby future states are dependent only on the

[27] Saunders, *The Ashgate Research Companion to Experimental Music*, p. 276.

present state.

Having designed this generative process, I decided that I wanted it to impact upon the large scale structure of the work. I therefore used it to create a series of sound files, each thirty minutes in duration. I chose this as the maximum possible length for the piece. Each was generated using a short sample from my source recordings with multiple instances of the process enacted at different playback speeds. As my motivation was to reveal hidden details within the source sounds, the speeds I opted for were successive halvings, resulting in a series of downward octave transpositions.

4.3 SCULPTING SOUND

As in *Shades*, my compositional strategy was to combine process with intuition. Having generated all the material for the piece, I could now proceed by a process of subtraction rather than addition. This is the very opposite of the 'blank page' phenomenon so often faced by composers. I see this approach as analogous with sculpture. Rather than starting from nothing, I was starting with the maximum available material and chipping away to reveal the piece within. As Michelangelo is thought to have remarked, "Every block of stone has a statue inside it and it is the task of the sculptor to discover it." This was the task I now sought to adopt. While some of the sounds were relatively static over the full duration, others varied a great deal. As the placement in time was fixed, this variation became intrinsic to the form of the work. The compositional process involved a great deal of intense listening as I isolated narrow bands of frequencies and searched for moments of interest. These moments often formed discrete sections which I chose to frame with periods of silence.

4.4 SPATIALISATION

I was keen for the spatialisation of this piece to create a sense of immersion and envelopment. I opted for an eight channel ring of speakers grouped into stereo pairs. By assigning each track to one of these pairs, I could create a stereo image for each sound from the Mid and Side components. I chose to keep these assignments fixed throughout the piece so that content originating from the same source sound was always linked to the same spatial position. The nature of both the source material and the generative process had many advantages in this approach. Several of the source sounds were quite similar, exhibiting only subtle differences. Within these sounds, the Brownian motion created an understated sense of change. Additionally, when working with these similar sounds, I often highlighted slight variations in frequency content. This meant that when these sounds were assigned to different pairs of speakers, they were effective in creating a unified and enveloping timbre with an absorbing internal motion. Other sounds, containing greater change, were combined to create a subtle sense of movement.

4.5 REFLECTIONS

Making this piece provided answers to some key questions I was facing as a composer. The absence of the performer in the realisation of fixed electroacoustic works creates a unique opportunity for 'absolute' composer autonomy. I have often been troubled by this lack of mediation and feel that, by introducing indeterminacy into the early stages of the compositional process, I was able to relinquish some control. By challenging myself to use only filtering and transposition, I engaged deeply with the source material and uncovered many hidden details within. I now see the potential for combining these simple processes in interesting and surprising ways.

The form of this work emerged as a direct result of my interaction with the material. I feel that it most closely resembles what Jonathan Kramer calls 'moment time'. This mosaic-like form is characterised by "self-contained sections, set off by discontinuities, that are heard more for themselves than for their participation in the progression of the music."[28] My use of silence and the fading in and out of each section adds to this feeling of segmentation.

[28] Kramer, *The Time of Music*, p. 50.

5 VEIL

5.1 INTRODUCTION

This piece was an opportunity to build on the techniques I had developed in *Glyptic* within the context of a live indeterminate work. It is the most open of the included compositions and entrusts a great deal of freedom to the performer. Exploring the balance of freedom and constraints was a key part of the compositional process.

5.2 THE ELECTRONIC PART

In devising the electronic part for the piece, my primary concern was that the performer had a simple and effective means of engagement. I chose to use a bluetooth pedal controller with two foot switches. These were used for starting and stopping the electronic processes. I developed the processes themselves to be self-sufficient so that no further layers of interaction were necessary. In doing so, I sought to automate techniques that I had used in the creation of *Glyptic*. I was keen that all electronic sounds used in the piece were derived from the performer and therefore decided to use live sampling as the basis for my approach.

The focus of the piece is the performer's relationship with the electronics. Decisions are determined by their perceptual judgements of this relationship and a feedback loop emerges. This results in a complex and evolving form. This complexity relies on the electronic part creating a certain perceptual ambiguity. It is for this reason that I was interested in utilising the phenomenon known as auditory masking. In particular, I wished to explore frequency domain masking between the soloist and electronics. I therefore focused my efforts on the use of critical bands. As Gareth Loy writes:

> These can be thought of as channels of frequency-selective psychoacoustic processing that affect our perception of pitch, loudness, and masking of frequency components lying within a critical frequency distance of one another.[29]

Although in reality the critical bands are continuous, it is useful to model the ear's spectrum as a set of 24 discrete bandpass filters. This is known as the 'Bark scale' (see Appendix B). I used the Bark scale as the basis for analysing the input sound and filtering the output. When the performer presses the right foot switch, a five second sample is recorded. While this is happening, the computer measures the peak amplitude of the signal as well as the peak amplitude in each of the 24 critical bands. When the five seconds have elapsed, these amplitudes are reported and the critical bands are ordered accordingly. A single band is randomly selected from the middle eight values of this ordered list. This central region proved to have the most potential for revealing hidden details within the sound. The peak amplitude of the unfiltered signal is divided by the peak amplitude of the filtered signal. This returns an amplitude value for the filtered output that makes the volumes equivalent. The output itself is generated by the same process that was used for *Glyptic* before passing through the filter. A random walk is taken around

[29] Gareth Loy. *Musimathics: The Mathematical Foundations of Music, Volume 1*. MIT Press, 2006, p. 176.

the five second sample, creating a constantly varying loop.

The masking effect itself is manifested in the combination of the acoustic and electronic sound. Each new electronic element enters while the performer continues the sustained sound from which it is derived. As the score specifically demands that this sustained sound be ‘unstable, unfamiliar’, there will be a great deal of subtle variation in both parts. The amplification of a single critical band has the potential both to reveal detail that was hidden in the sampled sound and mask frequencies present in the acoustic performance. It refocuses the attention of both listener and performer on these inner fluctuations and the interweaving of acoustic and electronic components. By following the instructions in the score, the performer then proceeds to transform the relationship of these constituent components in response to their perceptual experience. For a successful realisation, it is important that the electronics have the potential both to be more and less audible than the acoustic performer. This makes achieving the right balance especially important, as explained in the instructions preceding the score.

5.3 THE SCORE

Writing the score for this piece was an interesting challenge. I wanted it to allow many possible realisations and decided not to specify an instrument. I did, however, have the violinist Angharad Davies in mind for the recorded performance. As she is both an experienced improviser and performer of experimental works, the complex relationship between these two disciplines was at the forefront of my mind. As an improviser myself, I echo Rhodri

Davies's preference for "composition that takes me to areas that I wouldn't necessarily arrive at if I were left to my own devices."[30] Ultimately, I wanted the score to create a situation that would enable a unique dialogue to emerge between performer and electronics.

Having attempted a number of purely textual scores, the flowchart format proved to be the clearest and most succinct form of notation. The arrows create a clear visual representation of the possible pathways, while the boxes ensure that each decision is clearly delineated. Within this visual format, the choice of words and resulting tone are still significant. As John Lely has written, "The register of a verbal score is realised, even if unconsciously, by the scorer's choice of grammar."[31] The score is largely in the imperative mood, with statements issued as commands such as "Stop sustain". The first statement, however, "A sustained sound; unstable, unfamiliar", is notable for its use of the declarative mood. This is less assertive and creates a sense of openness, deliberately avoiding the word 'play' and omitting mention of the means by which the sound should be made. Finally, "Electronics in foreground?", uses the interrogative mood. This question forms the crux of the piece and crucially places perceptual judgements with the performer.

5.4 REFLECTIONS

The joy of handing a piece of this kind to a performer is not knowing exactly what to expect. It was fascinating to hear several interpretations and follow

[30] Saunders, *The Ashgate Research Companion to Experimental Music*, p. 257.

[31] John Lely and James Saunders. *Word Events: Perspectives on Verbal Notation.* Continuum, 2012, p. 8.

the different routes that were taken through the score. A single performance may explore just a small subset of the available possibilities. Some of the instructions are deliberately ambiguous and I was intrigued to hear how they would be interpreted. There is no indication, for example, as to how the electronics should be shifted to foreground or background. I was pleased, therefore, that timbral as well as dynamic change was explored in achieving this.

This piece was very much an experiment and the process of creating it has laid the groundwork for future works. I am eager to hear further interpretations by a range of performers and it is only then that I will be able to judge the success of the score. There is, perhaps, a tension between the use of psychoacoustic theory in the electronic part and the ambiguous nature of the instrumental part. I feel this reflects my compositional journey as I progressed from the initial impetus to the finished work. For me, the most exciting aspect of the piece is that the line between performer and electronics is often blurred and elements appear to shift in and out of focus. I would like to explore the masking phenomenon more directly in a future work, but I feel that its understated application in this piece enabled the transitions between these various states of fusion and flux.

6 CONCLUSION

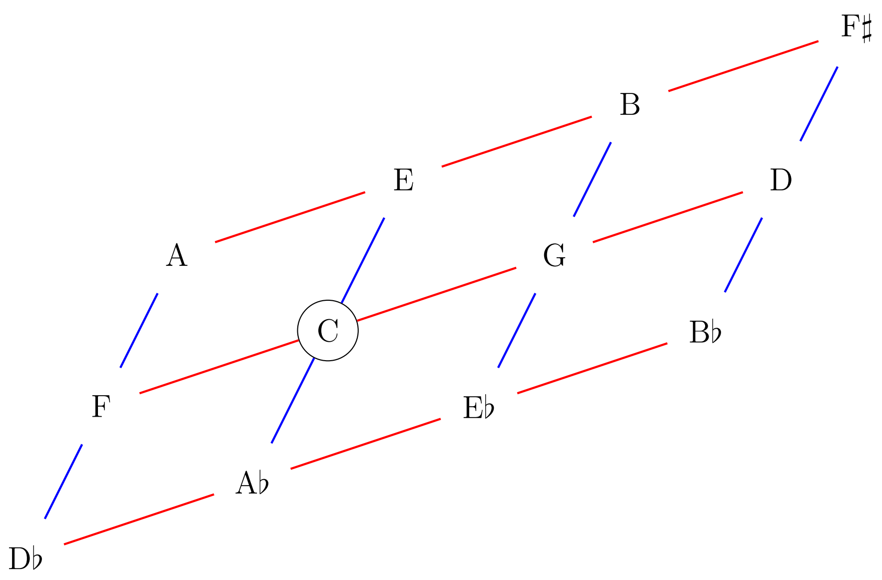
As has been discussed in depth, the four included works explored a variety of compositional techniques, concepts of time, notational approaches and uses of technology. In conclusion, however, it seems pertinent to examine some of the features they share in common.

All four pieces incorporate silence. This emerges as a key feature and is used to refresh focus and frame surrounding material, as well as build awareness of the performance space. *Shades* and *Glyptic* share a common approach to register. Both start in the middle range before opening out. The extremities of pitch are often used to create a void which is then filled. Although critical bands are not referenced until *Veil*, hindsight shows them to be relevant to all four pieces. The beating effects caused by the dyads in *Shimmer* result from the two pitches residing in the same band. I was drawn to these same beating effects when creating *Glyptic*, while the organising principle of *Shades* is the semitone.

All these features are evidence that strong subjective characteristics will emerge even when composing within strict bounds. Paradoxically, the desire to introduce a degree of nonsubjectivity, and create distance between myself and my material, has done much to develop my compositional voice. Additionally, detailed study of the compositional process has opened up further avenues for exploration.

Appendices

A THE FIVE-LIMIT LATTICE OF TWELVE NOTES



B THE BARK SCALE

Bark No.	Center Frequency	Critical Bandwidth	Lower Band Edge
0	50	80	0
1	150	100	100
2	250	100	200
3	350	100	300
4	450	110	400
5	570	120	510
6	700	140	630
7	840	150	770
8	1,000	160	920
9	1,170	190	1,080
10	1,370	210	1,270
11	1,600	240	1,480
12	1,850	280	1,720
13	2,150	320	2,000
14	2,500	380	2,320
15	2,900	450	2,700
16	3,400	550	3,150
17	4,000	700	3,700
18	4,800	900	4,400
19	5,800	1,100	5,300
20	7,000	1,300	6,400
21	8,500	1,800	7,700
22	10,500	2,500	9,500
23	13,500	3,500	12,000
24	19,500		15,500

C SHIMMER SUPERCOLLIDER CODE

```
// James Opstad (2017)

Routine({
  var forScore, baseFreq, durMin, durMax, fadeMin,
     fadeMax, silenceMin, silenceMax, parts, unisons
     , pages, play, playing, window;

  // boot server
  s.bootSync;

  // midi
  MIDIClient.init;
  MIDIIn.connectAll;
  forScore = MIDIOut.newByName("Network", "forScore"
     );

  // parameters
  baseFreq = 55 / 3;
  durMin = 32.0;
  durMax = 64.0;
  fadeMin = 2.0;
  fadeMax = 4.0;
  silenceMin = 8.0;
  silenceMax = 16.0;
  parts = Array.newClear(2);

  // part 1
  parts[0] = Pfsm([
    [0],
    [11, 12], [1],
    [9, 8], [2, 3],
    [11, 12], [1, 3],
    [10, 10], [4],
    [10, 9], [5],
    [14, 15], [6, 7],
    [10, 9], [5, 7],
    [12, 12], [0],
    ], inf);
```

```
// part 2
parts[1] = Pfsm([
  [0],
  [24, 25], [1],
  [16, 15], [2, 3],
  [24, 25], [1, 3],
  [20, 20], [4],
  [21, 20], [5],
  [27, 28], [6, 7],
  [21, 20], [5, 7],
  [24, 24], [0],
  ], inf);

// unisons
unisons = [[10, 10], [12, 12], [24, 24], [20,
   20]];

// pages
pages = [[24, 25], [16, 15], [20, 20], [21, 20],
   [27, 28], [24, 24]];

SynthDef(\sin, { |attack, sustain, release|
  var freq, sin, env;
  freq = baseFreq * \partials.kr([1, 1]);
  sin = SinOsc.ar(freq);
  env = EnvGen.kr(Env.linen(attack, sustain,
     release, curve: \sin), doneAction: 2);
  Out.ar(0, sin * env * 0.1);
}).add;

// wait for server
s.sync;

play = { |part, sin = 1|
  Routine({
    var stream, partials, dur, attack, sustain,
       release;
    stream = parts[part].asStream;
    loop {
      partials = stream.next;
```

```
      dur = rrand(durMin, durMax);
      attack = rrand(fadeMin, fadeMax);
      release = rrand(fadeMin, fadeMax);
      sustain = dur - attack - release;
      partials.postln;
      if(sin == 1, { Synth(\sin, [\partials,
         partials, \attack, attack, \sustain,
         sustain, \release, release]); });
            if(part == 1, {
              var page;
              page = pages.detectIndex({ |item|
                 item == partials; });
              forScore.program(0, page);
            });
      if(unisons.includesEqual(partials),
        { (dur - release).wait; },
        {
          dur.wait;
          if(part == 1, { forScore.program(0, 6);
             });
          rrand(silenceMin, silenceMax).wait;
        };
      );
    }
  }).play;
};

playing = Array.newClear(3);

      // create window to receive input from
         bluetooth foot switch
window = Window.new("AirTurn");
window.view.keyDownAction = { |view, char, mod,
   unicode, keycode, key|
  case
  { key == 16777237 }
  {
      playing[0] ?? {
          "play".postln;
          playing[0] = Routine({
              5.wait;
```

```
                playing[1] = play.(0);
                rrand(silenceMin, silenceMax).wait;
                playing[2] = play.(1, 0);
            }).play;
        };
    }
    { key == 16777235 }
    {
        playing[0] !? {
            "stop".postln;
            playing = playing.collect({ |item| item
               !? { item.stop; nil; }; });
        };
    };
  };
  window.front;

}).play(AppClock);
```

D GLYPTIC SUPERCOLLIDER CODE

```
// James Opstad (2017)

// Each code block should be executed separately

// SynthDef

SynthDef(\play, { |buffer, rate, startPos, attack,
   sustain, release, out|
  var play, env;
  play = PlayBuf.ar(2, buffer, rate * BufRateScale.
     kr(buffer), 1, startPos * BufSampleRate.kr(
     buffer));
  env = EnvGen.ar(Env.linen(attack, sustain, release
     ), doneAction: 2);
  OffsetOut.ar(out, play * env);
}).add;

// Buffer

b = Buffer.loadDialog(s);

// Instrument

~sustain = { |rate, out|
  var minDur, buffer, dur;
  minDur = 1;
  buffer = b;
  dur = buffer.duration;
  if(dur < minDur, { "Buffer too short".postln; }, {
    Routine({
      var fade, startPos, segDur, attack, sustain,
         release;
      fade = { rrand(0.25, 0.5) * segDur; };
      // initial values
      startPos = rrand(0, dur);
      segDur = rrand(minDur, dur * 0.5) / rate.abs;
      attack = fade.();
      loop {
```

```
        rate = rate * [1, -1].choose;
        if(startPos + (segDur * rate.abs) > dur, {
          rate = rate.abs * -1; });
        if(startPos - (segDur * rate.abs) < 0, {
          rate = rate.abs; });
        release = fade.();
        sustain = segDur - attack - release;
        \rate.postln; rate.postln;
        \dur.postln; dur.postln;
        \startPos.postln; startPos.postln;
        \segDur.postln; segDur.postln;
        \attack.postln; attack.postln;
        \sustain.postln; sustain.postln;
        \release.postln; release.postln;
        \.postln;
        s.bind({ Synth.grain(\play, [\buffer, buffer
          , \rate, rate, \startPos, startPos,
          \attack, attack, \sustain, sustain,
          \release, release, \out, out]); });
        (attack + sustain).wait;
        // new values
        startPos = startPos + ((attack + sustain) *
          rate);
        segDur = rrand(release * 2, (dur * 0.5) /
          rate.abs);
        attack = release;
      };
    }).play;
  });
};

// Record

~record = { |octaves, time|
  var numChannels, transpose;
  numChannels = 2;
  s.recChannels = octaves * numChannels;
  s.recHeaderFormat = "wav";
  s.recSampleFormat = "int24";
  transpose = Array.fill(octaves, { |i| 1 / 2.pow(i)
    ; });
```

```
  Routine({
    var play;
    s.record;
    play = transpose.collect({ |item, i| ~sustain.(
       item, i * numChannels); });
    time.wait;
    play.do({ |item| item.stop; });
    s.stopRecording;
  }).play;
};

~record.(6, 300);
```

E VEIL SUPERCOLLIDER CODE

```
// James Opstad (2017)

Routine({
  var inM, inS, mainOut, sampleDur, fade, attack,
     release, freqArray, bwArray, gSource, gEffect,
     source, buffer, filter, instrument, output,
     switch = 0, id = 0, window;

  // boot server
  s.bootSync;

  // parameters
  inM = 4;
  inS = 5;
  mainOut = 0;
  sampleDur = 5;
  fade = { rrand(5.0, 10.0); };
  release = fade.();

  // bark scale
  freqArray = [60, 150, 250, 350, 450, 570, 700,
     840, 1000, 1170, 1370, 1600, 1850, 2150, 2500,
     2900, 3400, 4000, 4800, 5800, 7000, 8500,
     10500, 13500];
  bwArray = [80, 100, 100, 100, 110, 120, 140, 150,
     160, 190, 210, 240, 280, 320, 380, 450, 550,
     700, 900, 1100, 1300, 1800, 2500, 3500];

  // groups
  gSource = Group.tail;
  gEffect = Group.tail;

  // busses
  source = Array.fill(2, { Bus.audio(s, 2); });

  // buffers
  buffer = Array.fill(2, { Buffer.alloc(s, s.
     sampleRate * sampleDur, 2); });
```

```
// outputs
output = Array.newClear(2);

// filters
filter = Array.newClear(2);

// sample input and measure peak amplitude in each
    critical band
SynthDef(\sample, { |buffer, id|
  var input, record, inputPeak, filterArray,
     peakArray;
  /*input = In.ar(tempBus, 2);*/
  input = SoundIn.ar([inM, inS]);
  record = RecordBuf.ar(input, buffer, loop: 0,
     doneAction: 2);
  inputPeak = Peak.ar(input);
  filterArray = BPF.ar(input, freqArray ! 2, (
     bwArray / freqArray) ! 2);
  peakArray = Peak.ar(filterArray);
  SendReply.kr(Done.kr(record), '/peaks', [
     inputPeak, peakArray].flatten(2), id);
}).add;

// play overlapping segments
SynthDef(\segment, { |buffer, rate, startPos,
   attack, sustain, release, out|
  var play, env;
  play = PlayBuf.ar(2, buffer, rate, 1, startPos *
      BufSampleRate.kr(buffer));
  env = EnvGen.ar(Env.linen(attack, sustain,
     release , curve: \sin), doneAction: 2);
  OffsetOut.ar(out, play * env);
}).add;

// filter by critical band and scale the amplitude
SynthDef(\filter, { |in, freq, bw, slope = 1, ampM
   , ampS, attack, release, gate = 1, id|
  var filter, output, msDecode, env;
  filter = In.ar(in, 2);
  // output = filter;
```

```
  output = Select.ar(slope, Array.fill(2, { filter
      = BPF.ar(filter, freq, bw / freq); }));
  output[0] = output[0] * ampM;
  output[1] = output[1] * ampS;
  msDecode = [output[0] + output[1], output[0] -
     output[1]];
  env = EnvGen.ar(Env.asr(attack, 1, release, \sin
     ), gate, doneAction: 2);
  SendReply.kr(Done.kr(env), '/free', 0, id);
  Out.ar(mainOut, msDecode * env);
}).add;

// wait for server
s.sync;

// create sustained sound from overlapping
   segments
instrument = { |buffer, out, rate = 1|
  var minDur, dur;
  minDur = 1;
  dur = buffer.duration;
  if(dur < minDur, { "Buffer too short".postln; },
      {
    Routine({
      var fade, startPos, segDur, attack, sustain,
          release, filterFreq;
      fade = { rrand(0.25, 0.5) * segDur; };
      // initial values
      startPos = rrand(0, dur);
      segDur = rrand(minDur, dur * 0.5) / rate.abs
         ;
      attack = fade.();
      loop {
        rate = rate * [1, -1].choose;
        if(startPos + (segDur * rate.abs) > dur, {
            rate = rate.abs * -1; });
        if(startPos - (segDur * rate.abs) < 0, {
           rate = rate.abs; });
        release = fade.();
        sustain = segDur - attack - release;
        s.bind({ Synth.grain(\segment, [\buffer,
```

```
            buffer, \rate, rate, \startPos,
            startPos, \attack, attack, \sustain,
            sustain, \release, release, \out, out],
             gSource); });
         (attack + sustain).wait;
         // new values
         startPos = startPos + ((attack + sustain)
            * rate);
         segDur = rrand(release * 2, (dur * 0.5) /
            rate.abs);
         attack = release;
      };
    }).play;
  });
};

// receive peak amplitudes in each critical band
OSCdef(\peaks, { |val|
  var inputPeaks, peakArrays, ampArrays, order,
     choice, freq, bw, ampM, ampS;
  inputPeaks = val[3..4];
  peakArrays = [val[5..28], val[29..52]];
  ampArrays = peakArrays.collect({ |peak, i|
     inputPeaks[i] / peak; });
  order = ampArrays[0].order;
  choice = order[rrand(8, 15)];
  // filter
  attack = release;
  release = fade.();
  filter[id] !? { filter[id].release; };
  id = val[2];
  freq = freqArray[choice];
  bw = bwArray[choice];
  ampM = ampArrays[0][choice];
  ampS = ampArrays[1][choice];
  filter[id] = Synth(\filter, [\in, source[id],
     \freq, freq, \bw, bw, \ampM, ampM, \ampS,
     ampS, \attack, attack, \release, release, \id
     , id], gEffect);
  output[id] = instrument.(buffer[id], source[id])
     ;
```

```
    freqArray[choice].postln;
  }, '/peaks');

  // free filter synth and stop instrument
  OSCdef(\free, { |val|
    var id;
    id = val[2];
    output[id].stop;
    filter[id] = nil;
  }, '/free');

  // create window to receive input from AirTurn
     bluetooth footswitch
  window = Window.new("AirTurn");
  window.view.keyDownAction = { |view, char, mod,
     unicode, keycode, key|
    var switchFunc;
    switchFunc = { |val| switch(val, 0, 1, 1, 0); };
    case
    { key == 16777237 }
    {
      switch = switchFunc.(switch);
      filter[switch] !? { switch = switchFunc.(
         switch); "Not ready".postln; } ?? {
        Synth(\sample, [\buffer, buffer[switch], \id
           , switch], gEffect);
        "Sample".postln;
      };
    }
    { key == 16777235 }
    {
      filter[id] !? { filter[id].release; "Stop".
         postln; };
    };
  };
  window.front;

}).play(AppClock);
```

REFERENCES

Crispin, Darla. *Artistic Experimentation in Music: An Anthology*. Leuven University Press, 2014.

Feldman, Morton. "Crippled Symmetry". In: *Essays*. Ed. by Walter Zimmermann. Beginner Press, 1981.

Fox, Christopher. "Why Experimental? Why me?" In: *The Ashgate Research Companion to Experimental Music*. Ed. by James Saunders. Ashgate, 2009.

Gottschalk, Jennie. *Experimental Music Since 1970*. Bloomsbury Academic, 2016.

Harrison, Bryn. "Cyclical Structures and the Organisation of Time". University of Huddersfield, 2007.

Korb, Wolfgang. *CD sleeve notes for Stefano Scodanibbio Geografia Amorosa*. Trans. by Steven Lindberg. Col Legno, 2000.

Kramer, Jonathan D. *The Time of Music*. Schirmer Books, 1988.

Lely, John and James Saunders. *Word Events: Perspectives on Verbal Notation*. Continuum, 2012.

Loy, Gareth. *Musimathics: The Mathematical Foundations of Music, Volume 1*. MIT Press, 2006.

Lucier, Alvin. *CD sleeve notes for Alvin Lucier Crossings*. Lovely Music, 1989.

— *Music 109*. Wesleyan University Press, 2012.

Messiaen, Olivier. *The Technique Of My Musical Language*. Alphonse Leduc, 1944.

Oliveros, Pauline. *Deep Listening: A Composer's Sound Practice*. iUniverse, 2005.

Reynell, Simon. "Chiyoko Szlavnics interview". In: *Canadian Composers Series*. Another Timbre, 2017.

Saunders, James. *The Ashgate Research Companion to Experimental Music*. Ashgate, 2009.

Voegelin, Salomé. *Listening to Noise and Silence: Towards a Philosophy of Sound Art*. Bloomsbury, 2010.

Xenakis, Iannis. *Formalized Music: Thoughts and Mathematics in Music*. Pendragon Press, 1992.