The Cyber-Guitar System:
A Study in Technologically Enabled Performance Practice

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A thesis submitted to the Faculty of Humanities, University of the Witwatersrand,
in fulfilment of the requirements for the degree of Doctor of Philosophy
March 2017

Declaration

I know that plagiarism is wrong. Plagiarism is to use another's work and to pretend that it is one's own.

I have used the author date convention for citation and referencing. Each significant contribution to and quotation in this dissertation from the work/s of other people has been acknowledged through citation and reference.

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

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Abstract

This thesis documents the development and realisation of an augmented instrument, the cyber-guitar, expressed through the processes of artistic practice as research. The research project set out to extend my own creative practice on the guitar by technologically enabling and extending the instrument. This process was supported by a number of creative outcomes (performances, compositions and recordings), running parallel to the interrogation of theoretical areas emerging out of the research.

In the introduction I present a timeline for the project and situate the work in the field of artistic practice as research, explaining the relationship between research and artistic practice as research. Following on from this chapter one, Notation, Improvisation and the Cyber-Guitar System, discusses the impact of notation on my own education as a musician, unpacking how the nature of notation impacted on improvisation both historically and within my own creative work. Analysis of practices such as graphic notation led to the creation of the composition *Hymnus Caesus Obcessiones,* a central work in this research.

In chapter two, Noise, Music and the Creative Boundary I consider the boundary and relationship between noise and music, beginning with the futurist composer Luigi Russolo. The construction of the augmented instrument was informed by this boundary and aimed to bring the lens onto this in my own practice, recognising what I have termed the ephemeral noise boundary. I argue that the boundary line between them yields the most fertile place of sonic and technological engagement.

Chapter three focuses on the instrumental development and a new understanding of organology. It locates an understanding of the position of the musical instrument historically with reference to the values emerging from the studies of notation and noise. It also considers the impacts of technology and gestural interfacing. Chapter four documents the physical process of designing and building the guitar. Included in the appendices are three CDs and a DVD of recordings of the various performances undertaken across the years of research.

Acknowledgements

I would like to thank firstly my supervisors, Professor Jeanne Zaidel-Rudolph, Dr Grant Olwage and James Sey. Without their continued support and guidance this would not have been possible. I also extend a special thanks to Andeline do Santos for extensive advice and guidance on content and formatting throughout this research.

Secondly I would like to thank the musicians who have so generously collaborated with me through the various concerts and performances, without whom the performance testing would have also been impossible. They are (in no particular order): Jacob Israel, Justin Badenhorst, Carlo Mombelli, Joao Orecchia, Jonno Sweetman, Lukas Kytnar and Lukas Ligeti.

Lastly I would like to thank all who have given moral and emotional support in this pursuit, without them the work would have faltered: Iliska Crossley, Noel and Val Crossley, Wim and Querardien van Vliet, Belinda Wrigley, Dr Cameron Harris, Hayley Elwyn, Caroline Smith, Stuart Goodwin, Dayne Marshall, JD Kustom guitars, Dr Chris Letcher, Professor Gerrit Olivier, Professor Christo Doherty, Tegan Bristow, Roger Pearce and Johan Olivier.

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Introduction

Over the course of my career as a creative musician my focus has shifted several times: Starting out as a classical guitarist, I then performed as a traditional jazz guitarist, and later turned to experimental improvised music with an increasing interest in electronic elements. It was as my artistic interests moved into areas that required increasing electronic engagement that the aim of this research emerged. The specific line of enquiry that I grew interested in related to augmenting the instrument of the guitar so as to facilitate my evolving aesthetic desires. My goal was not to invent a new musical instrument or to abandon the guitar. Rather, I hoped that in taking account of both the advantages and limitations of the guitar I could form a unified artistic motivation for expansion of the instrument and the related fields with which it would subsequently interact.

Project Timeline

The cyber-guitar system was first imagined in the late 2000s and was born out of frustrations while performing with some of my own project bands as well as working with other artists.[1] In one of these bands in particular, The Jonathan Crossley Electric Band, I found myself spending large portions of time during concerts on my knees, trying to play the guitar with the left hand only whilst using my right hand to adjust effects parameters.[2] This research project endeavours to explore means that enable the extended controlling of effects parameters on the instrument in ways that do not impact my existing performance technique. I desired to retain the performance skills I had learnt on the instrument over decades of practice while exploring ways to add controls that would not impact on these techniques.

The cyber-guitar system was designed to have three distinct components: an effects-enabled instrument, a looping system, and controls attached to parts of the performer's body such that they did not impact on standard performance technique. These components were developed

[1] During the course of the project many potential names were given to the instrument. A long-time collaborator, Carlo Mombelli, kept referring to it as the cyber-guitar, and the name stuck.

[2] Other projects included performances with Carlo Mombelli, The Aike Project, Soft Serve and Donkey.

as follows: the guitar build took place in 2011, the loop system was designed in 2012, and the extended controls in 2013; all of which I discuss in detail in the thesis. During these periods the guitar was tested extensively in performance. Test performances took place in two formats. Firstly, I performed weekly with the Carlo Mombelli Trio from the start of 2011 until early 2014, and secondly I used specifically designed concerts to interrogate the unfolding research developments. Although the weekly concerts also played an integral role in shaping the design, in this thesis I focus predominantly on the concerts that were created to examine features of the research project. Four of these concerts, listed below, are all included in either CD or DVD format in the appendices. They were:

- What if the machines spoke back to you? August 2011, appendix A,
- What if the machines took control? September 2012, appendix B,
- The Cyber-Guitar recital, *Hymnus*, March 2014, appendix C, and
- 3 Cities, Crossley, Ligeti and Sweetman in Concert, April 2015, appendix D.

The cyber-guitar tour of the Czech Republic and Slovakia which took place in November 2013 was not recorded.

In the initial stages of the research the lines of critical enquiry were not completely clear and avenues were explored that later fell away as the project evolved. The central fields of engagement emerged during 2011 as the build proceeded and performances began. These crystalized around aspects of notation, improvisation, noise and instrumental design.[3] Another significant development that emerged was the need to situate these lines of enquiry not only directly in relation to the cyber-guitar, but also to understand them contextually. This required reflexive examination of events in my musical development dating back to my early training as this shaped the artistic and aesthetic goals that were fuelling the project's formation. As Nicholas Collins has said, "buried in the mechanics of instrument design can be the seeds of music" (1991:41).

[3] The instrumental design incorporated gestural interfacing as the body controllers were developed from 2012 onwards.

Defining and developing an instrument

The field of new instrument creation (including interfaces and acoustic instruments) has seen explosive growth in the decades since the 1980s, with new instruments created and shared at a rapid rate. Evidence of this is in the prominent international competitions and conferences focused on instrument development: The Margaret Guthman competition, the New Interfaces for Musical Expression conferences, and the Ars Prix Electronica.[4] The diversity of new systems that have emerged from the stimulus provided by these 'official' platforms as well as from designers working outside these arenas is impressive. Laetitia Sonami's work with the Lady's glove is one such example. An ongoing project first developed in 1991 for a performance at the Ars Electronica festival in Linz, it used a variety of triggers and sensors built around a glove. The glove was worn on the left hand allowing the right hand to operate a mixer and other controls. Sonami's pioneering work has led to similar developments recently made more widely known by the British artist Imogen Heap, whose TED talk of 2012 brought wider public awareness for the various iterations of the glove and which led to the formation of the non-profit group mi.mu, a group of artists, musicians, scientists and technologists that includes Heap, dedicated to researching and expanding the capacities and fields of use for sensor glove systems (www.mimugloves.com).[5]

The mi.mu glove represents a recent example of a completely new instrumental innovation that has begun to be used extensively by a diverse range of artists, but this broad use has not been the case for the greater majority of new instruments (Jordà, 2004:1). Sergi Jordà also highlights how "many new instruments are being invented [but] too little striking music is being made with them" (2004:59). In addition to instrumental designs that are completely new, there are those that use certain parts of the frame of an existing instrument whilst

[4] The Margaret Guthman Competition is hosted at Georgia Tech Center for Music Technology annually and aims to identify the newest musical instruments and technologies. (http://guthman.gatech.edu/) NIME or the conference for New Interfaces for Musical Expression has run annually at various locations since 2001. This conference has hosted many new instruments and has a wealth of past conference papers available. (http://www.nime.org/) The Ars Prix Electronica is an annual competition hosted by Ars Electronica in Linz. It is not exclusively musically focussed but spans a multitude of fields. (http://www.aec.at/prix/en/)

[5] Others associated with mi.mu include Thomas Mitchell, Kelly Snook, Seb Madgwick, Hannah Perner-Wilson, Adam Stark, Rachel Freire and Chagall van den Berg.

reducing the functionality of other parts.[6] When an existing instrument, which remains active in its functionality, is extended it is referred to as either an augmented instrument or a hyperinstrument.[7] By augmenting an existing instrument, rather than inventing a completely new one, the instrument thus becomes available to the wide range of practitioners already creating music with the standard instrument. This has been the approach of a number of musicians such as Lukas Ligeti's work on Don Buchla's 'Marimba Lumina', Michel Waisvisz's 'Hands' and Nicholas Collins' 'Trombone Propelled Electronics'. In the case of both Collins' and Buchla these design innovations were built around the frame of existing instruments.[8] According to Joseph Thibodeau,

> as a subject of study, augmented instruments represent a fascinating intersection between traditional technique and modern technology. They are a crossbreed of extremely mature acoustic musical theory with as yet immature but immensely powerful gestural sound control (2011:1).

Tod Machover's work at the Massachusetts Institute of Technology Media Lab has pioneered the field of Hyperinstruments since 1987 and this has seen a proliferation of developments in the practice of specifically extending existing instruments as well as bringing technological tools such as the joystick into instrumental practice. Projects emerging from this research such as the Hyperviolin Bow expressly use aspects of the existing instrument in ways that generate new control parameters and these can be mapped and integrated into the performer's instrumental practice. Diana Young's continued work with the Hyperbow uses the changes in the use of the bow to map the changes in 'bow position, speed, acceleration, downward force and angle of the bow' (Young, 2002:1) .

Young further elaborates that 'there is a great need for the development of new musical interfaces that may respond to the smallest and most subtle gesture of an accomplished musician' (Younng 2002: 1). In the field of augmented instruments and Hyperinstruments this goal has taken the form of augmentations across a wide variety of control methods. For

[6] See *The Evolution of 'Trombone-Propelled Electronics* (2009) by Nicolas Collins for one key example of this.

[7] Alternative terminologies are hybrid, extended, meta and hyper instruments (Miranda & Wanderly, 2006).

[8] Whilst Ligeti was already a virtuoso drummer and percussionist before performing on the Marimba Lumina, Collins had never played a traditional trombone prior to developing the new instrument. Regardless Collins' use of the core aspects of the trombone design married with electronics can be deemed both intimate and virtuosic.

example these have included the use of gestural mapping through visual means as well as the attachment of triggers to existing instruments. In their paper "Use of Body Motion to Enhance Traditional Musical Instruments" (2014) Frederico Visi, Rodrigo Schramm and Eduardo Miranda discuss the use of a Microsoft Kinnect in mapping the gestures of an electric guitarist. In this application the performer had sensors placed on key points on the instrument to facilitate accurate tracking of gestures. The project also used flex potentiometers and accelerometers attached to an customised Arduino based circuit board to generate additional control values.

In this case, as in the work of many others, the extended body is mapped to control data changes. These types of projects greatly informed decisions and explorations I made during the development and building stages of this project. For instance the work of flautist Cléo Palacio-Quintin uses the standard frame of the flute and directly attaches technology to the instrument, in similar ways to the previously mentioned work by Nicolas Collins. Palacio-Quintin has been working with the hyperflute for more than fifteen years and has developed a variety of iterations of the project mapping controller values through MAX MSP. She says of the instrument that 'the extended flute enables me to directly control the digital processing parameters as they affect the flute's sound while performing and allows me to compose unusual electroacoustic soundscapes' (Palacio-Quintin 2008,1). She notes that any skilled performer has a high awareness of the state of their body during performance with their instrument and that whilst 'auditory feedback is obviously very important but the physical sensation of playing comes before the perception of the sound' (1). From these examples it became clear that the cyber-guitar system should augment the existing instrument in clear ways that engaged with and extended my existing instrumental practice without impeding the performer-instrument relationship.

Consideration of the performer-instrument relationship is central to the successful development of any instrument, existing, augmented or new (Tanaka, 2000:399). This is evident in the work of Atau Tanaka, the Japanese researcher whose new instrument systems such as Biomuse, Soundnet and The Global String have been ground-breaking. For instance, the Biomuse system uses electroencephalogram (EEG) and electromyogram (EMG) sensors

attached to the performer that trigger audio and control events through MAX MSP.[9] Whilst his instruments are completely new in design, Tanaka is acutely concerned, whilst conceptualising or imagining new instruments and interfaces, with the performer-instrument relationship as well as audience reception. This reveals a preoccupation with the nature of instruments as a way to ensure the successful and continued use of an instrument's development (Wanderly & Battier, 2000:389). Tanaka himself affirms that "a musical instrument, as part of an engaging performance, becomes an expressive device in the hands of the performer" (2000:389).

The nature of the relationship between the performer and the instrument may unfold in many different ways. But an ideal relationship creates a gestural language for the instrument whilst, in the process, allowing for an idiomatic language for the instrument to develop. The various core features that emerge from this relationship include note ranges, articulation and instrumental techniques. These in turn map out the boundaries of what are usually deemed extended performance techniques and, through the extension of techniques, the boundaries of what would be considered idiomatic gradually change over time. The performer's efficiency in using the instrument (mastery, in the traditional sense) also affects the relationship between the performer and the listener. For Tanaka, "the listener's perception of the music is contingent on the instrument's efficiency at transmitting the performer's musical expression, and the performer's ability to channel his creativity through the instrument" (in Wanderly & Battier, 2000:389). He criticises performances where it is obvious to the listener that the performer is struggling to manage the control of the instrument ("What patch is active now?" "How do I get this working?"), and he believes that this apparent lack of mastery negatively impacts the reception of the music created.

For Tanaka an intimate relationship between the performer and the instrument needs to be apparent to the listener and must be a goal of any instrumental design process, whether this be a new instrument or, as in the case of my research, an augmented one. The outcome must be a "situation where the performer can attain a level of intuition with regard to his

[9] MAX MSP is a visual programming language for media made commercially available by the company, Cycling 74. The Soundnet system is a large sensor based instrument for multiple users created by Sensorband (Atau Tanaka, Zbigniew Karkowski and Edwin van der Heide), mounted on scaffolding with the performers climbing on ropes that activate the data sensors. The global string project is a multi-user instrument that senses and activates vibrations across a data network.

instrument where he is not preoccupied with every detail of its manipulation" (Tanaka in Wanderly & Battier, 2000:399). Intuition is a core component of the capacity to improvise with an instrument, especially under ensemble conditions, with intimacy between the user and the instrument crucial to successful intuitive practice. Lack of intimacy impacts negatively on the free flow of intuition whilst using the instrument in performance. As the processes of improvisation, which have been central to this project, require creative and performance freedom, intuition is vital to successfully engaging in the practice of such. As all the performances I have given have improvisation at their core the cyber-guitar required user-instrument intimacy as a key part of its design.

The intention of my research, then, grounded in a lifetime's investment in performance on my instrument the guitar, was to imagine ways to augment the instrument and my practice on it through physical, technological and musical innovations. The developmental areas focused on were thus ones that would grow and expand my own artistic practice in expected as well as unexpected and unpredictable ways. I desired to play with the question "What more can I do with the instrument and my body, and what might this sound like"?

Jordà reminds us that "instruments are used to play and to produce music, transforming the actions of one or more performers into sound" (2004:1). Thus any technological innovation or addition should be done in a way that allows the performer to link the addition directly to a sonic event. In *The Body in Electronic Music* Jan Schaefer makes this position core to his analysis of the place of technology in musicking:

> When performing with a traditional instrument on a high level of concentration, focus and presence, many motor functions, perceptual adaptations and adjustments occur automatically and remain un- or pre-conscious. This is the result of the extensive training an instrumentalist has received. The integration of all of these functions happens naturally because the relationship with the materiality of the instrument as the physical manifestation of an acoustical principle – string, column of air, drum-skin or any other sounding body (vocal chords being a special case) – conforms to our knowledge of and skills within the physical world. This knowledge is a natural part of our human existence. Instrumental training imprints the musician's body with instrumental and corporeal schemata that are guided through auditory, but also tactile, kinaesthetic and proprioceptive feedback (2012:3).

My argument, which I pursue in this project, is that technological augmentation of an instrument must result in the eventual absorbing of the techniques and innovations, facilitated through design, build, and testing, into standard practice on the instrument.

Artistic practice as research

The artistic outcomes of the concerts I presented during the course of this project provided a timeline which allowed the tracking of the research areas and located the project in the realm of artistic practice as research. Darla Crispin defines artistic practice as research in the field of music as necessitating "locating the contextual information and the musical practice within a rigorous methodological framework" (in Doğantan-Dack, 2015:58). Methodologically, this research project sought to interrogate, through performance on the cyber-guitar system, different types of composition, form, improvisation, sonic outputs, gestural interfacing and technological design through the means of instrument design innovation. These practices and their concomitant concepts and ideologies were additionally explored through critically reflecting on my own historically entrenched understandings of musical roles, practices, and objects, such as 'the performer', 'the composer' and 'the instrument'.

Crispin's contribution to Mine Doğantan-Dack's collection of essays *Artistic Practice as Research in Music* (2015) has been particularly useful to me in shaping an understanding of the area of artistic research that this project falls within: artistic practice *through* research. Crispin categorises artistic research into four areas: musical practice, informed musical practice, informed reflective musical practice, and research in-and-through musical practice (2015:58).

As a performer my work up until the commencement of this research project would have been primarily located in the first two of these categories, musical practice and informed musical practice. The first of these, musical practice, can be understood as the act of performing or creating music, in which the musical practitioner is engaged in their craft solely in the process of creation, in an imagined isolation. The second category is one in which the practitioner studies information surrounding the realisation of the material in which their creative work exists. As a young student, prior to tertiary education, I dedicated myself

principally to the physical processes of learning an instrument, mastering the technical requirements needed to use the instrument, often without concerning myself with the contextual basis or the motivation for such endeavours. As I moved into tertiary education I became concerned with a variety of standard historical-type contexts: periods of composition, lives of the composers, the historical nature of the genres, thus enabling a more informed performance practice.

As a professional artist I began to question my own relevance as a classical musician, and this caused me to reflect on the value of my work. As such my thinking and practice began to align more strongly with Crispin's conceptualisation of informed, reflective musical practice. Crispin explains this category as involving the locating of one's reflection on one's musical practice within a methodological framework, in this case within a series of concert presentations and the research directions they afforded. My understanding of the fields in which I was operating broadened, while I gathered further contextual information and interrogated it, continuing to question the significance and validity of my work. This process brought me into a period of reflection from which the specific aspects of this research project arose.[10]

Having created a number of musical works, recorded them, and reflected on the outcomes of the concerts in which they were performed I then began to ask questions that directed me to interrogate past work. This interrogation provided me with clearer direction for future developments. Crispin's last category, research in-and-through musical practice, refers to a process wherein the artistic practice and research and reflection on these practices form a circular relationship, where there is a continual flow of information between the areas. I elected to design and conduct the current study within this approach as I observed that practical performances were the most effective way in which to direct the nature of the instrument's design and the attendant research areas. The methodological framework employed within the current study built on the previous three categories of practice, the work emerging from them, my reflections on their nature and the recorded creative outputs. And

[10] The period preceding the start of this research project involved performances and album recordings with The Jonathan Crossley Electric Band (2006-2011), Soft Serve (2008) and Aike (2010-2011).

the scope of the research broadened to include related fields such as noise, machine interfacing, gestural interfacing, cybernetics and notation.

The areas of musical practice I sought to interrogate were all viewed through the lens of the creative work undertaken and tracked through the periodic concert performances given. In addition to the various areas interrogated I also felt it important to visually document the design and construction of the cyber-guitar system. Crispin notes:

> Whenever the boundary of Artistic Research is approached, however, a new set of imperatives obtains; not only must a rigorous methodological framework be structured through which the research may be conducted, but it must also be articulated in such a way that the findings of the research may be shared with the wider research community – a community that may, or may not, be fully conversant with the kind of musical/research practice being undertaken (2015: 59).

Doğantan-Dack's work on the role of the musical instrument in performance as research, whilst principally concerned with the piano, offers important insights as to the place of instruments in general in music research. The common neglect in musical thought towards the instrument stems from an emphasis on text which prevailed throughout the twentieth century in musicology. "If one thinks of music as in essence constituted by the abstract structural relationships between notatable parameters such as rhythm and pitch, the material conditions of music's production and reception rapidly fade into insignificance: both the instrument and the performer are thrust into the periphery of musical ontology and epistemology (Doğantan-Dack 2015:173). This emphasis on text in music research has tended to exclude focus on, amongst other things, instrument design and augmentation, gestural interfacing and improvisation, which are core elements of my research.

Tanaka's assertion that musical outputs emerge from the instrument and grow with design modification (2000:399) was acutely present in this project due to the prominence of improvisation. One could argue that this is so in any case where the outputs are improvised. In the realm of artistic performance as research, "understanding the affordances of different kinds of musical instruments becomes crucial in exploring the means through which new insights and knowledge might emerge" (Doğantan-Dack, 2015:173). One might add that the

musical outputs emerge in the same way through the affordances of the musical instrument and these move through any level of design innovation or augmentation.

Improvisation is a key creative focus of my research and in the design of instruments, including that of the cyber-guitar, because it shapes the music that emerges from them. This is because free improvisation allows the user to explore the instrument in uninhibited ways. Christoper Redgate documents his research into the development and extensions of the oboe as well as the centrality of improvisation in this process, concluding that "as a performer I have found improvisation to be a very useful tool for the exploration of sonic resources and an indispensable one in developing an understanding of the key-work of a redesigned instrument" (Redgate, in Doğantan-Dack 2015:203). As the augmented oboe developed (in this particular case without electronics) Redgate argues that it is in the processes of improvisation that the fullest capacities of the instrument are most easily mastered and discovered. These discoveries were then communicated to composers and new works were written. The works, in turn, required a complete revision of existing notational systems and the development of new ones.

In the tradition of performance practice as research the cyber-guitar suggested "new ways of thinking, new ways of interacting, new ways of organizing time and textures; new ways, in short, of playing new musics" (Jordà, 2004:59). Thus I allowed the design process to facilitate the choice and interrogation of the central aspects of composition, form, improvisation, sonic outputs, gestural interfacing and technological design. I was inspired by Jordà's comment that whilst many new instruments are made little striking music is made on them (2004:1) and thus desired that my instrument should indeed permit striking creative music making. And I hope that the sonic realisation of this project, presented in the accompanying DVD, gives some sense of the cyber-guitar's sonic capacities.

Outline of the thesis

In chapter one, "Notation, improvisation and the cyber-guitar system", I examine notation and improvisation through the lens of my own practice before and during the development of the cyber-guitar. Doğantan-Dack reminds us that "for the artist-researcher, any journey of discovery and creation originates and unfolds within an already established individual

creative discourse and praxis, having a distinctive relationship with existing cultural discourses and traditions" (2015: 176). I consider the impact of these elements on my previous work, on each other and on the project. I then chart how the various concert presentations and compositions gave rise to the work *Hymnus Caesus Obcessiones,* which was composed for the examination recital in 2014. In chapter two, "Noise, Music and the Creative Boundary" I explore the boundaries between noise and music, discussing historical examples of this boundary and its employment in music. This chapter also introduces what I have framed to be the most fertile area of engagement with noise and music: the ephemeral boundary between them. I discuss how the unexpected sonic events that have been part of the instrument's output have shaped the approaches to composition, improvisation and collaboration whilst using and developing the system. Chapter three, "Designing the cyber-guitar: Understanding instrumental design and organology in context", presents the various theoretical areas that framed the conceptual design of the system. I consider a recent revision to the concept of organology, aspects of cyber-cultures and the prosthetic nature of musical instruments. Finally, in chapter four, "Design and Construction", I detail the building process for the guitar, the looping system and the body controllers or exoskeleton. In this chapter I have chosen to document the construction process photographically rather than through circuit or other types of diagrams. This approach was drawn from the field of circuit bending or hardware hacking and the pictorial approach is consistent with much of the documentation from this field referenced as part of this project.[11]

Included with the document are the four previously mentioned audio recordings. Each of these represents different phases during the research process. The first two recordings, of the concerts *What if the Machines Spoke Back to You?* (2011) and *What if the Machines Took Control?* (2012), document the initial stages of the design and musical exploration. The design stage at this point was concerned with the physical testing of the instrument as various technological elements were added to the system but also specifically explored notational practices (both in the presence and absence of a score). The DVD documents a concert presented in March 2014 as an examined part of the research project. This concert was given in collaboration with Carlo Mombelli (bass), Justin Badenhorst (drums) and Jonno Sweetman

[11] The two accepted pioneers of this field are Nicholas Collins and Rheed Ghazala. For an example of the pictorial approach see Collins' "The Evolution of 'Trombone-Propelled Electronics'" (2009).

(drums) with the completed cyber-guitar system and featured the composition *Hymnus Caesus Obcessiones* which emerged from the explorations in notation described in chapter one. The final CD recording included is titled *3 Cities*: *Crossley, Ligeti and Sweetman in Concert*, and is a recording of a performance given in April of 2015. I have included this recording as it represents a period in which the cyber-guitar system had moved from a research project into standard or familiar use. This recording thus provides a marker as to the types of creative outputs that may emerge going forward with the instrument.

Crispin notes that "musical artists do not invariably frame their activities from the onset as being *either* musical practice *or* research; often, the associated activities move from one kind to another" (in Doğantan-Dack, 2015:59). This has been patently true throughout the various stages of this project. The areas of engagement I mentioned in the chapter outline have impacted each other in ways that created a flow of influence and have informed their collective critique throughout the ongoing development of the cyber-guitar system.

Chapter 1

Notation, Improvisation, and the Cyber-guitar System

The development of the cyber-guitar system required me to consider the notation and scoring of musical materials in a number of ways, and also to reflect on how scoring practices are related to performance, specifically improvisation which has been the dominant mode of performance explored on the cyber-guitar for this project. In their respective developments notation and improvisation have an intertwined history. This chapter presents a discussion of the historical process that gave rise to graphic notation as well as the evolution of improvisation. This is as the work I composed for the final performance of this project, titled *Hymnus*, was written within the traditions of the graphic score and requires extensive improvisation. This is couched within a personal narrative, illustrating how these two areas of musical practice manifest in my own history as a performer and artist and through the cyber-guitar system's design, specifically in this chapter as the system's looping apparatus impacts performance. Within this discussion I integrate relevant interrogations of class and pedagogical approaches.

On Notation

I began studying the classical guitar at the age of six and conventional notation was the medium through which I learned. As a young student my initial conceptual understanding of who a musician is and what a musician does, and even my appreciation of music itself, were immediately shaped by the processes of learning notation. The developmental processes in notational practice and the systems of pedagogy that support them served to quickly delineate and separate the roles of composer and performer in my mind: the composer is a far-removed entity (essentially reaching the status of 'demigod') and the performer is the faithful executor of the score. As I took on the role of a classical music performer it did not occur to me to

simultaneously consider composing due to the categorical limitations of the role definition.[12] These formal, one could even argue 'moral', divisions also confined the practice of improvisation (described to me as 'messing around') to 'lighter' or demotic musics. Ironically, it was the country and folk guitarist John Denver who was the main inspiration for my decision to study the guitar and not one of the 'great' composers. Thereafter it was the manner in which the greatness of the classical composers, such Mozart, Beethoven and Wagner, was emphasised by which my aesthetic values were subsequently structured.

In secondary school I met other musicians who were able to simply 'jam' together, whereas even with a Trinity College grade eight qualification in classical guitar I was unable to participate. I secretly experienced this inability to jointly improvise, specifically without the use of a score, as humiliating. When discussing this with my teachers they reframed my experience as an affirmation of class value: I was a 'serious' musician and, as such, these skills were not required. Improvisational skills were, essentially, 'beneath' the more serious art music performer and were indicative of the 'obviously' lower aesthetic value of the repertoire played by popular musicians. Retrospectively, it is clear how this class distinction (described further by Bennett et al., 2009) is enforced through the absence (rather than presence) of a skill or set of skills. I found these aesthetic values fully entrenched in my understanding of music. I religiously accepted my teacher's guidance and also unconsciously linked these musical perspectives to class aspirations within my own family.

In reading Nicolas Collins' account of his early university tuition I found resonance with my own experience. Collins attended Wesleyan University as the strength of the Indian music department appealed to him; however, he was encouraged to study under the composer Alvin Lucier. He notes:

> although I walked directly from my tabla lesson to my class with Lucier, I never thought to incorporate Indian instruments into my electronic work; likewise, despite the obvious

[12] See Taruskin (1995) for a further articulation of relationships between text, notation and performance.

> visceral similarities between Robert Ashley's *Wolfman* and my Jimi Hendrix records, my obsession with feedback never led me to bring an electric guitar into the studio (Collins, 2012:4).

Although he is speaking from the perspective of a composer his explanation of unquestioned genre separation within his educational journey parallels my own.

My grandfather was a lower working class citizen in Northern Ireland during the 1950s. After returning from military service in the Second World War he found himself unable to 'ascend' from his lower working class existence, in part due to suffering from post-traumatic stress. My father internalised negative associations regarding my grandfather's class and life situation. Studying Western art music was a way, he imagined, of transcending his station in life. My grandfather did not share this outlook and, thus, my father's goal of pursuing classical vocal tuition was never realised. Years later when I expressed interest in music study (particularly the music of John Denver) my father pressed for classical guitar studies, as this field was superior in his mind. As I began formal studies these internalised family values paralleled the art music value system that informed conventional Western pedagogy.

This mechanism of social aspiration through music is hardly exceptional. Since the late eighteenth century art music in Western middle class culture had a growing social imperative as it gradually disconnected from its aristocratic associations and became a value-based middle class activity. The middle classes took up music as a serious activity without knowledge of how music functioned within the court or the behaviour and activities of musicians within that system. They therefore invented or reimagined its nature as having certain characteristics linked to their aspirations. Carl Schorske comments on this with particular reference to Austria, where music, architecture and theatre were key traditions of the Catholic aristocracy. He explains how, at the turn of the century, that if "entry into the genealogical table was barred to most, the aristocracy of the spirit was open to the eager, the able, and the willing ... the democratisation of culture, viewed sociologically, meant the aristocritisation of the middle class" (1981:296). Aside from being socially aspirant, the new

middle class felt it a duty to educate the larger populace about and through musical performances. Robin Moore states, "the drive to educate citizenry about classical music came not from the court or aristocracy, but from the wealthy burghers, whose ideas about art music were often less informed, and more reverent and limiting" (1992:73).

Moore charts the demise, and even active removal, of improvisation from Western art music from the late eighteenth century through to the mid-twentieth century (1992:62-62). With the rise of the middle classes music acquired a higher status (socially and as a commodity) than it previously had within the court system where its function was more directly linked to entertainment. For the middle classes music was no longer principally an entertainment source, but was an idea and object containing value in and of itself. It was a marker of sophistication, status, social ascendancy, and even intelligence and knowledge, imparted through the new-found practice of public performances.

The new middle class desire to educate the masses regarding music, amongst other things, can be regarded as a locus for the building of Western art music pedagogy. In *The Decline of Improvisation in Western Art Music* Moore alludes to the fact that the shift from aristocratic performance culture to public, middle class educative concerts represents an important transition (1992:73). Where the courts were populated by musicians who were professionals with the capacity for improvisation this was not the case in the performance culture driven by the middle class. Not only did improvisation as a key musical capacity decline, but the place of notation within art music pedagogy grew apace (although improvisation was still expected in certain limited areas of performance, such as in cadenzas). Musical tuition, as the pedagogical approach conferred through notation and the conservatoire, was born during this time.

As music notation took on increasing importance the idea of composition itself became intrinsically linked to the practice and process of notating. As such, notation enabled the rise of the role and identity of the composer, as completely separate to that of the performer. This bond between composition and notation has persisted even into the recent past and has

impacted improvisational practices in a number of ways. George Lewis (1996) has explored the sociological nature of improvised music stemming from Charlie Parker (be-bop) and John Cage (aleatoricism or indeterminacy) in relation to the concept of composition. He describes improvisation and composition as representative of what he calls Afrological and Eurological practices respectively, arguing that they are instances of different approaches to notation and composition. Lewis summarises five defining characteristics of a musical work, proposed by theorist Carl Dahlhaus (1979:10-11), who argued that these characteristics must be present for a work to be categorised as a composition:

> A composition is, first, an individually complete structure in itself. Second, this structure must be fully worked out. Third and fourth, it is fixed in written form in order to be performed. Finally, what is worked-out and notated must constitute the essential part of the aesthetic object that is constituted in the consciousness of the listener. That these five characteristics identify the very notion of composition as European in nature is asserted by Dahlhaus at several points. The dialectic between composition and notation, according to Dahlhaus, is critical to the notion of composition itself. Compositions that are worked-out without being notated, in Dahlhaus's view, are neither compositions nor improvisations. (1996:96)

If, in this thinking, a composition (to the exclusion of freer forms of improvisation) has to be notated in its entirety before it is considered as such then the notation itself is all-defining and the function of the performer is to render the composition audible exclusively through this vehicle with no conceptual room for a non-notationally bound form of improvisation. This approach informed the pedagogical imperatives that underpinned my own musical development and were embedded in my music value system. Classical music, observes Moore, "had a new social function superseding many of its previous uses, and could meet the demands of concert goers without being improvised" (1992:75). As improvisation was now associated with the lower or popular musical forms it was, thus, no longer a requirement for professionally trained musicians.

This aforementioned divide between performers and composers, one that informed my early understanding, was one that maintained the divide between compositions and improvisation in my own practice. In my musical education, this paradigm remained unchallenged until the third year of my university studies when the impulse to compose my own music began to disrupt what I had taken for granted. I hadn't at the point considered what improvisation meant in practice but some of the types of works I was writing and performing retrospectively were improvisatory in nature. I began to explore writing for my instrument and 'tinkering' with signal effects, to the concern of some of my tutors, and I performed these works at every opportunity I could find within the university context. I was also part of an avant-garde collective called the Sunless Ensemble along with James Sey, Arnaud van Vliet, Christine Bill and Iliska Crossley. The multi-media works we performed in Johannesburg and Durban consisted of video, readings and music, with live and electronic aspects. Although this ensemble only performed publically twice (in 1997 and 1998) it was a unique group in the South African landscape at the time, with multimedia and music elements not as yet commonplace in the performance market.

Through these endeavours I came to recognise that the skill missing in my musical 'arsenal', the one that could potentially release me from historical pedagogical constraints and from an absolute dependency on notation, was improvisation. After having completed my Bachelor's degree in music I had a life-changing lesson with the late South African jazz guitarist Johnny Fourie in 1998. I presented to him an E major prelude from the Bach lute suite BWV 1006a and a Helmut Jasbar arrangement of *Mercy Mercy Mercy* by Joe Zawinul.[13] At the end of this sizeable presentation Fourie simply replied, "That's nice". He then played a complex chord and said, "Now improvise over this". I could do nothing. With one chord he cut directly to my weakness: total dependency on notation. It was a singular demonstration of the absence of my capacity to improvise with any kind of immediacy. The unspoken, imagined and pedagogically enforced division between improviser, composer and performer—so deeply entrenched in many musicians educated in the Western art music system—crumbled in a single lesson. A key element of the current autoethnographic research project has been to

[13] I had studied with Helmut Jasbar in Vienna in 1995. Jasbar was a rising classical guitarist and, at that point, I could not understand why he was composing and recording his own avant-garde music (because, after all, he was a classical guitar performer).

understand these tensions within my personal practice. I have interrogated this, in part, through examining the technological process involved in the design of cyber-guitar system which I explore in chapters three and four.

After the initial lesson with Fourie I undertook an intensive Master's degree under his tuition. My initial intention was not to study jazz specifically, but to learn improvisation according to what was then my limited understanding of the term. I had come to Fourie with a specific interest in artists who appeared on the ECM label, most notably the guitarist Ralph Towner who performed original compositions and improvisations on the classical guitar. [14] Towner fascinated me at that point as his music "transcends the dualities of jazz/classical and composed/improvised music" (Towner, 1985:4). Although trained as a classical guitarist he is able to improvise and compose freely, but in a style that I felt was neither specifically located in an American jazz tradition nor limited to the classical guitar repertoire. Under Fourie I intended to study jazz to gain skills of improvisation that I could apply to my own musical interests. After a short period of time under Fourie's tuition, however, I felt compelled to immerse myself in the jazz tradition, aspects of which I found immensely challenging. Firstly, the techniques required to operate effectively inside the tradition were such that, at times, I felt as if I had never played the guitar before. Secondly, the modes of thinking about music, and for example the rhythmic elements and aural requirements were foreign to the training I had received up to that point, and the nature of the syncopated feel and swung performance were novel to me. With these realisations I set about thoroughly studying the technical (harmonic, modal and rhythmic) aspects of the jazz tradition.

As I plunged into the world of learning jazz under Fourie I mistakenly believed that I would have to turn my back on classical music, a notion that was supported by colleagues working in both genres and professional influences such as concert promoters. The perceived tension between the worlds of classical and jazz performance was in line with the aesthetic that was prominent in jazz from be-bop onwards: "Improvisation in this process becomes more and

[14] ECM is a German label led by Manfred Eicher, and has specialised historically in what is known as 'third stream' music, which is conceptualised as inhabiting a space between classical and jazz, and also features improvisation.

more an aesthetic policy: in a society in which Black values in jazz became stronger, improvisation can serve as a model opposing European cultural tradition" (Knauer in Turkenberg, 2004:8). I had naively believed that I could avoid engaging with the social history of jazz. The consequence of this ideological musical separation was that my classical performance engagements decreased. As a newly professional (and emboldened) jazz musician the world of jazz performance shaped the way I engaged with my instrument. Jazz standards and the skill required to improvise over chord changes became my exclusive devotion until the completion of my jazz performance Master's degree.

On Improvisation

It was only many years later (almost a decade after beginning to study jazz) that I sought to establish my own groups to perform original works and to challenge the tensions described in the previous section. I returned to exploring earlier fields of interest such as the ECM stable as represented by the guitarist Ralph Towner. This, in turn, led me to other areas of musical practice such as the school of British improvisers including Keith Tippett, Cornelius Cardew, Derek Bailey, AMM, The Spontaneous Music Ensemble, Fred Frith (of Henry Cow) and Chris Cutler (Henry Cow, Cassibear and Art Bears). These musicians and performer-composers carved a path from the 1960s onwards that was specific to neither of the musical traditions described above (classical or jazz) and actively sought out new methods for improvisation, performance and composition (Bailey, 1992: 130). They aimed not to be aligned to either of the sociological implications of the Afrological or Eurological perspectives (as in Lewis's (2002) definition), choosing neither to affiliate themselves with nature of the composer inside Cageian aleatoric systems nor with the harmonic nature of post-bop or the styles of free improvisation developing out of jazz. For the purposes of this research it is the acknowledgement of the centrality of the individual creator in both perspectives that bears reflection: In Cageian aleatoricism the composer is both continually present and exerting influence and in jazz the lead improviser is the central figure, be this in either post-bop or free ensembles. The aspect of the British school that sets it apart is the equality within group practice, a shift away from the individual, whilst still drawing on aspects of both in practice. Watts argues, 'the music of the Spontaneous Music Ensemble

came about from the fact that we didn't want to dote on American jazz, but take the spirit of that music for ourselves, and move things along in the way *we* wanted' (2003: 138). Perhaps the physical distance of this group of practitioners from mainland America and the segregation of improvisation through race in the jazz improvisational heritage allowed them to operate outside certain constraints.

They developed a different musical landscape, presenting performances of complete group improvisation, not centred around a specific composer or lead improviser, for which materials were not prepared in advance; and even discussions surrounding content were avoided. They also actively sought not to exclude any type of instrumentation or material (both jazz and aleatoricism can clearly be heard in the work of certain performers), and incorporated electronic instruments with acoustic instruments and extended techniques.[15] In expressing their concerns regarding distinguishing their work from improvisational practice from these two schools, Bailey argues, "nothing…is quite as interesting as improvisation, and nothing is quite as dull and boring and dead as knowing precisely what is going to happen" (in Watson, 2004:2). It is this impulse that separated the British school from lead improviser centred jazz practices or the ever-present hegemony of the composer as expressed through Cageian aleatorism. This impulse was not completely unique to the British school discussed here and can be clearly seen in the work of American contemporaries and predecessors such as John Coltrane (in his late period), Cecil Taylor and others. However in the context of this research project and influence on my thinking and practice the work of the British school was central.

The AAM ensemble and the group of musicians affiliated with Cornelius Cardew took emotion as a structural and aesthetic value system rather than class, race or previous aesthetics (Prévost 1995:27).[16] Interaction within the improvisation(s) through foregrounding the processes of communication was viewed as the prime structural imperative. The communicative quality of the interchange (as enacted and experienced by the participants)

[15] There were earlier adoptions of electronic instruments within improvisational practice in America such as in the work of Sun Ra, however it is the desire for equality to be conferred to all contributors and instruments within the British school which is of particular significance to this research.

[16] See also Harris (2016:42).

both during the performance event and retrospectively is the lens through which the event is deemed successful. This allowed the British improvisers to explore improvisation in new ways, freed from the genre impositions that privileged harmony and form in improvisational practice. It also allowed them to sidestep certain presuppositions with regards to instrumentation that dominated the Western art music and post-bop jazz traditions. The interconnectivity of electronics within all aspects of the groups work was a significant addition to their practice. The specific way in which electronics were used in this context was also different from its use in *musique concrète* and *elektronische Musik.* AMM approached the use of electronics in less of a pre-conceived way, not in the structured ways that *musique concrète* and *elektronische Musik* applied technologies. Composer Michael Nyman noted that this approach seemed intrinsic to the ensemble's practice and that "AMM seem to have worked without the benefit or hindrance of any kind of prepared external discipline" (1999:129).

Whilst AMM focussed on 'pure' improvisation it is worth considering that the ensemble began during 1965 at the time during which Cardew was composing *Treatise* (1963-1968). Cardew's seminal work from this period consisted of 193 pages of graphic notation, with each page containing one empty line of stave notation beneath the graphs. Some of the structural elements of the aesthetics implied in *Treatise* bear a similarity to his work in AMM. Thus Eddie Prévost finds a shared similarity between the creative endeavours of *Treatise* and AMM in resisting the very area in which they are located. "There is no evidence that Treatise was informed by (and thereby represents) a particular range of philosophical considerations. Just as there is no evidence that an "AMM improvisation was informed by anything that bears the generally accepted idea of a composition" (Barett 2017:1). At this time Cardew was adopting aspects of indeterminacy into his work in a manner that set about bringing the performer and composer into dialogue. This may have played out in a reciprocal way between *Treastise* and AMM's endeavours. Harris comments that it "was emerging that Cardew's preoccupation with indeterminate processes was as much, if not more, to do with people than with music" (2013:37). This is not to suggest that indeterminacy was about the composer and performer coming into dialogue as certain aspects of chance intrinsic to Cage's creative process remove the agency of the performer altogether. Cardew chose rather to draw from indeterminacy the suggestion of form through graphic representation, feeling that the

shapes and forms in *Treatise* gave rise to a memory of a music not yet heard and would; thus, draw from the performer a new or unexpected type of improvisation. He states that drawings offer their own interpretations: "In how far your 'notation plus rules' determines the sound, is a matter of your system's completeness" (Cardew, 1961:23).

Other artists from the British improvisation scene who I 'discovered' included Henry Cow and Chris Cutler. Although formed a number of years later, in 1968, Fred Frith and Tim Hodgkinson's group Henry Cow drew elements from the musical philosophies of AMM in ways specifically related to the interrogation of boundary and form (Jones, 2016:1). Henry Cow's music developed at a time when rock was re-inventing itself and was drawing on aspects of Western art music and improvisation. According to Jones,

> Henry Cow were committed to forging a contemporary rock music, rock that eschewed the vacuous commercialism and ubiquitous Anglo-American influence of the music industry, rock that was revolutionary in form as well as in content. Against the backdrop of wide spread student riots, the Vietnam war, Prague spring, Situationism and the unravelling social fabrics of the late 1960's, Henry Cow caught the comet of confrontation and counter-culture experimentation that flared through the skies after the summer of love died. New compositional possibilities were being explored by progressive rock ensembles like The Soft Machine, Faust, Magma, AMM and Pink Floyd, groups that rejected the cul-de-sac of the serialists and radically reappraised both rock and contemporary composition through the new vocabularies of playing and recording together (1995:11).

The grouping of musicians Jones cites includes progressive rock groups such as Soft Machine, Faust and Henry Cow alongside AMM, which was not a rock ensemble. Frith recalls: "I bought the first AMM record in 1969 and it had a big impact on me; made me listen differently" (Frith interviewed by Jones, 2016:1). One can deduce from Jones' and Frith's remarks that AMM played an influential role in the development of both the movement broadly and Henry Cow specifically.

Although not a founding member of Henry Cow the drummer Chris Cutler was a pivotal member of the group and has been a vital protagonist in the continuation of what Nic Jones has called "musique actuelle". Jones describes musique actuelle as "a quicksilver appropriation and reassembly of the sonically familiar–television, pop tunes, film noir, free jazz, modern arts, cultural icons, folk songs, the classical repertory and the dope vernacular of the street–into a new, surrealistic whole" (1995:7). Cutler learned much from AMM and his various interfaces with Cardew and has written extensively on music, even coining the term 'plunderphonics'.[17] In particular I wish to consider Cutler's approach to the rationalisation of notation and Western music history due to his diverse musical practice that traverses composition, improvisation and performance within multiple genres which has proven useful for the purposes of this thesis as Cutler's views, in particular, liberated my binary thinking. His perspective offers another path for engaging with the idea of improvisation both with and without notation. In *File Under Popular*, Cutler provides insight into these practices specifically. Here he divides Western musical practice into three categories: "THREE MEMORIES, THREE MEDIA, THREE MODES OF PRODUCTION" (Cutler, 1991:24; emphasis in the original). These categories are, firstly, "Biological memory: the folk mode", secondly "Written/printed memory: the classical or art music mode" and, thirdly, "Recording - - direct transcription of sound: a new mode" (1991: 24). Cutler defines the first category, that of biological memory, as representative and maintains this to be the main function attributed to music prior to the introduction of notation and the 'commoditisation' of musical practice. He lists the characteristics of this mode as follows:

> *First,* the medium of its musical generation and perpetuity is tradition and is based in Human, which is to say *biological*, Memory. This mode centres around the EAR and can only exist in two forms: as sound and memory of sound.
>
> *Secondly*, the practice of music is in all cases an expressive attribute of a whole community, which adapts and changes as the concerns and realities it expresses – or as the vocabulary of the collective aesthetic – adapts and changes. There is no other external pressure upon it.

[17] See John Oswald's essay "Plunderphonics, or Audio Piracy as a Compositional Prerogative" (1985) which outlines the nature of plunderphonics; in short, the sampling and re-contextualizing of materials into new compositions.

> *Thirdly*, there can be no such thing as a finished or definitive piece of music. At most there could be said to be 'matrices' or 'fields'. Consequently there is also no element of personal property, though there is of course individual contribution.
>
> *Finally*, there is no productive distinction between the roles of composer and performer. The generation and production of music is a socially seamless and single process and one in which improvisation plays or has a central part (Cutler, 1991:25-26).

While Cutler presents the folk mode of production as the principal location of musical practice before the introduction and functional adoption of music notation, he does not confine this mode to pre-notation and argues that this mode of practice still exists. Once commoditised (printed or re-arranged), though, these works cease to operate within this mode. For example, in the later nineteenth century folk songs that were recorded, re-arranged, and notated were then sold. They then existed as a commodity and this changed the form of the work. After being notated the works ceased to operate in the realm of memory, and were used to cater to a trained market of middle class amateur musicians. Notation, then, not only commoditised the work, but also participated in amplifying class distinctions. By notating the working class song, the printed version of the song, according to Cutler, appropriates the music to the action of class distinction (1991: 37).

Cutler's second mode (written/printed memory) first surfaces in the medieval church in Europe, and whilst forms of notation existed prior to this, he argues that the adoption of notation at this time became a negation of the folk mode and an elevation of the printed form. In many ways the second mode is a move against the folk mode and its processes of operation. As previously noted the rising bourgeois culture with its deployment of musical practice into cultural ownership and social ascendancy created a market that propelled the decline of the improviser and 'unschooled' musician. Cutler lists the three attributes of this mode of practice:

> *First*, as a fixed memory, external to its user, notation cannot organically adapt, or forget itself. In this sense a score is a definitive version and every score is finished. As a

score this version can be circulated and stored. It is the first form in which music can become property.

Secondly, notation is a medium which encourages and reinforces a specialising division between Composer and Performer. This is a division which becomes more absolute as its productive potential is unfolded (leading eventually to a destructive contradiction).

Thirdly, notation is primarily a medium of the EYE, not the EAR. It is thus subject to the laws which govern visual systems of representation. Melody and the division of time into equal parts for instance are horizontal, harmony is vertical. Notation is the medium of the fugue, of mathematical calculation, of the wide harmonic extensions of Polyphony and Counterpoint, of invert and retrograde melody, of the abstract and personal marshalling of massive orchestral voices – and indeed of the 'industrialisation of music' (1991:28).

This new language of notation assumed dominance through Western art music's subsequent history and, over time, increased in complexity, as is evident in some twentieth-century modernist scoring practices. Notation became increasingly specific and detailed as composers' desires grew more exacting. The requirements for the performer became ever more specific, with less room for creative forms of interpretation or improvisation. Eventually composers brought notation to such levels of complexity (most notably under serialism) that precise performative execution of the score became increasingly impossible. Performance began to buckle under the "constraints of oppressive notational complexities" (Tilbury, 1983:5). In the twentieth century composers such as Varèse and Honegger began to dream of machines that could execute the music to its highest level as a solution to this impasse, faithfully rendering the notational complexities in ways a human performer was not able to.

Notational complexity in itself was not the only solution or realisation of musical development. During the early twentieth century, for example, musical developments such as the *Intonarumori* of the futurists and later *musique concrète* presented significant challenges to the dominant notational system in the West, requiring sounds and sound events to be

represented that were well beyond the system's ability to do so. New methods of performance and creation, and new instruments and methods of presentation, often required that the 'distance' between composer and performer was narrowed, with the futurist composers performing on their own machine-like instruments using what can be considered to be the earliest version of a graphic score. Thus, although the literature typically refers to graphic notation being an innovation of the period between the 1950s and 60s in Western art music, the first clear example of a graphic score was in the notation system developed by Russolo for the *Intonarumori* (Telin & Hathaway, 2015:1). Russolo's notation maintained a five-line stave system, but departed from standard note-based nomenclature, opting instead for the use of solid visual blocks of material. This type of graphical approach to notation only materialised in its full force in the 1950s and 60s (Kojs, 2011).[18]

As recording technologies developed they too began to reshape musical practice. Cutler (1991:33) refers to recording as the next mode of production, asserts that it was a "qualitative advance" in music; one which he argued reconciled the composer and performer. He lists the qualities of recording or the use of recorded material as:

> *First, recording* throws the life of music production back onto the ear. As with folk music, the first matter is again Sound. Recording is the memory of sound.
>
> *Secondly*, recording makes possible the manipulation or assembly of sound, or of actual performances, in an empirical way; that is to say, through listening and subsequent decision making.
>
> *Thirdly*, the actuality of performance is not lost, but is freed from time; it can be taken apart. Recording has encouraged the use of the studio as an *instrument* rather than merely as a documentary device. Music can be assembled both vertically and horizontally over time, moulded and remoulded.

[18] Kojs explains that "Luigi Russolo, John Cage, Mauricio Kagel, Fluxus musicians, and Scratch Orchestra associates were among the first to develop graphical and verbal instructional choreographies which suggest musical actions" (2009:286).

> *Fourthly*, it must be clear that recording places an emphasis firmly on performance, and optimally indeed **is** a medium of composition *for performers*. In other words, it strongly favours the reuniting of those two roles.
>
> *Fifthly*, more than this: Constructive decisions in the assembly of sound are concrete and empirical and can be reached through discussion. A personal vision is no longer the necessary mediator between composition and realisation. Where Jazz developed improvisation into a high art, recording allows its extension into composition (Cutler, 1991: 34-35; emphases in original).

While Cutler's theory of music history can be critiqued, for example, in relation to the broad generalisations upon which it is based, his divisions within Western music history highlight questions of notation and improvisational practice that are often not foregrounded in historical narratives. Cutler's consideration of notation informed my own research project from the outset and, throughout the developmental stages of the project; it provided a lens through which I could consider the choice of works for exploration and creation in the performances centred on the cyber-guitar system.

On Notation Again

In Western music history as the notated form ascended and improvisation declined music existed as an object separate from the performer and the performance. The score became inherently valuable as a commodity in and of itself. It was a new commodity with the accomplished performer being prided on the ability to give an accurate reading. This remains so in much Western art music practice and the "larger part of classical composition is closed to improvisation and, as its antithesis, it is likely that it will always remain closed" (Bailey, 1992:59). Bailey discusses how, since its invention, the score has gradually come to set itself apart as something of great value and significance, as a piece of art, elevated in value beyond the performance and performers. Thus, as a performance "musical work ceased to be, little by little, the expression of an experienced psycho-physiological continuum – on the spot and at the moment it is experienced" (Bailey, 1992:59), and became a fixed and singular event,

trapped in time through the confines of the score. Due to this veneration of the score the composer was elevated to a position of greater importance than the performer in the image of a bourgeois imagined aristocratic power relationship (Moore, 1992: 80).

In the early twentieth century the ever more specifically-directed and detailed scores reached new heights of specificity under integral serialism. In fact the score became an outworking for the rigours of compositional method. In Pierre Boulez's *Piano Sonata no.2*, for example, "melodic content is almost completely dissolved" (Morgan, 1991:341) under the requirements of integral serialism as facilitated through the score. The score becomes an entity in itself, with the composer communicating stringent compositional requirements via the production of the score, and the performer being tasked with trying to present these accurately. This extreme authoritarian prescriptiveness by the composer for the performer via the score denied any drive towards improvisation or composition on the part of the performer. According to Christoph Cox,

> Deeper philosophical and political concerns also contributed to the move away from conventional staff notation. Politicised composers such as Cardew rejected the traditional score for supporting a hierarchical division of labour that required performers to subject themselves to the will of the composer. In contrast, the indeterminacy of graphic notation helped to dissolve this hierarchy, instead fostering an active collaboration between the two parties (in Cox & Warner, 2010:188).

Cardew (1975) considered the score to be dictatorial and as a Marxist rejected the score's supremacy. He viewed notation (as Cutler also did later on) as a means of maintaining the status divisions between composer and performer. Cardew's position was informed through his studies of the integral serial method and later forays into aleatoricism, which he explored after hearing John Cage's compositions in a performance in London by pianist David Tudor (prior to 1961). Whilst there were earlier forays into indeterminacy by Charles Ives and Henry Cowell, Cage emerged as the central figure within this predominantly American movement (Cushman, et al., 2012: 32).

In the U.S., from the 1950s onwards, the growth of indeterminacy within composers' practice can be viewed as a turning away from the absolute rigour of integral serialism. Roger Sutherland writes that "the European serialists and the American experimentalists proceeded from diametrically opposed ideological positions" (1994:139). Indeed many of the compositions arrived at through the rigorous application of serial procedures to *all* aspects of musical composition were chaotic, arbitrary and indeterminate in their audible result. Cage studied with Cowell and Arnold Schoenberg and, thus, was exposed to both the rigours of serialism as well as Cowell's early forays into indeterminacy. Later, Cage was significantly influenced by Edgar Varèse, specifically his inclusion of all sounds as musical entities. This inclusive approach led Cage to assert (on the subject of indeterminacy),

> first, [that] music is an 'organisation of sound' with 'sound' defined in the broadest possible sense encompassing all types of noise as well as 'normal' musical events; second and as a consequence, that the present methods of writing, principally those which employ harmony and its reference to particular steps in the field of sound, will be inadequate for the composers, who will be faced with the entire field of sound (in Morgan, 1991:359-360).

The most influential composition in this regard is Cage's *4'33"*, in which the performer remains on stage for the duration of time specified in the work's title, and the background noise is brought into focus through the absence of activated sound on the part of the performer. The inclusion of all sound into the domain of music served as a challenge to performance and notation.

The use of indeterminacy and sound take different forms in different compositions. In the series of works bearing the title *Construction* (1939-1942) Cage introduces noise elements through the inclusion of percussive metal objects. In works for 'prepared piano' objects were inserted between the piano strings thereby changing the instrument's conventional sound qualities. Cage's methods for composing with these materials stemmed heavily from his

understanding of form and the temporal structure guiding his compositions. Robert Morgan explains how

> Cage developed what he called a new 'method of writing music' to accommodate these unusual materials. Treating musical form as a sort of 'empty container' he set up for each composition a series of proportional time units measured by precise numerical calculations. Once this abstract durational structure—the 'container'—had been determined, he could insert whatever sounds he wished, relying upon the prescribed proportional relationships to provide a larger temporal or rhythmic framework (1991:360).

Whilst the materials (or sounds) and the structure were carefully designed, the link between the two was, in process, essentially arbitrary. Cage explained that "the method was that of considered improvisation ... The materials, the piano preparations, were chosen as one chooses shells while walking along a beach" (in Morgan, 1991:361). The compositional process elevated sound for sound's sake, where each and every sound is a musical event. These sounds, moreover, need not have any relation to each other. The sound is the message. With this in mind Cage fully adopted indeterminacy so as to allow the compositions to unfold either for the composer, or with the composer-improviser. Cage's view was that the composer must "give up the desire to control sound, clear his mind of music, and set about discovering means to let sounds be themselves rather than vehicles for man-made theories or expressions of human sentiments" (in Morgan, 1991:362).

In 1950s' New York several composers gathered around Cage. These included Earle Brown and Morton Feldman. They shared a fascination with the visual arts of the time, especially abstract expressionism. For the expressionists the materials and surface constituted the artwork itself and their work challenged the viewer through the presentation of material as message. A synergy emerged between these artists and composers as sound itself had become

elevated as the vehicle for musical communication, rather than in prior musical practices in which communication was encapsulated in the rigours of harmony and form.[19]

Alongside this canvas of indeterminacy and the fascination with the visual, the interest in graphic notation developed apace. Whilst graphic notation as a form of musical representation had existed from medieval times, wider usage of the practice only came to light in the 1950s and was enthusiastically taken up by composers such as Cage, Browne and Feldman within this school of composers (Henderson and Stacey, 2014: 16).

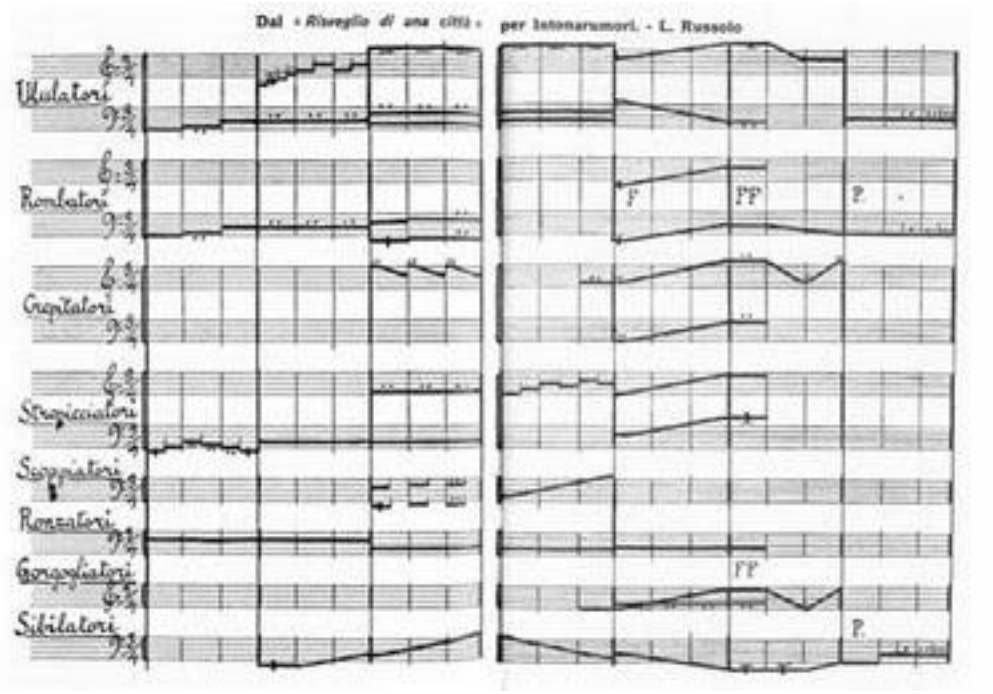

Figure 1: Extract from Luigi Rusollo, *Intonari* (1913).

As noted earlier Russolo had produced graphic scores for his *intonari* (noise-making machines) in response to the inadequacies of conventional notation (see fig. 1). Russolo used graphic notation only as a method for including the *intonari* in conventional musical ensembles to perform what was structurally conventional music at the time. It was never an

[19] Feldman had a strong relationship with Mark Rothko, composing *Rothko Chapel* for an exhibition of the latter's work. Much has also been said regarding the similarities between Cage and Jackson Pollock, although in later years Cage seemed to shy away from comparisons with Pollock (Revill, 2014).

artistic goal of the futurist composers to directly modify the music through the interrogation of notational convention and they rather aimed to find pragmatic ways to include sonic elements (see, for example, Venn, 2010:11). Theirs was rather an instrumental innovation first and foremost. The growth of graphic notation in the 1950s, however, was propelled by the notion that loosening the constraints implicit in the use of the score would free musical creation itself. This stood in stark contrast to the score-based constraints of integral serialism.

The emergence of electronic and tape music in the 1950s also called for new notational techniques. Cox asks, "How could one score factory noises, or the sweeps and squiggles of sine tones? More often than not, composers opted for a direct visual translation of the sonic material" (2010:188). Early graphic scores sometimes included notation as well as new symbols invented by the composer for the representation of non-traditional sound selections. The graphic notation also left much interpretation open to the performer. With the addition of indeterminate elements the performer became more involved in creative decisions. This represented a re-merging of the roles of performer and composer, not as an improvised practice in the sense of Cutler's folk mode, but rather as a new way of merging the two roles. In doing so it undid the rigidity inherent in the functions that notation seems to accord to different musical practitioners (Haynes, 2007: 104).

This interest in blurring the boundaries between composition and performance also reveals the influence of jazz. Indeed, the generation of composers considered here was raised during jazz's golden age and, in some cases, graphic scores mark a meeting point between the European and the African-American musical traditions. For example, "inspired by Cage, Brown and Feldman, Anthony Braxton turned to graphic notation as a way to structure the sonic chaos of free jazz and to provide a meditative focal point for collective improvisation" (Cox in Cox & Warner, 2010: 188). There were of course select exchanges between the differing approaches to improvisation, notably in the work of Anthony Braxton and Derek Bailey, but the lines of division between the two, as expressed in the American traditions, were evident and remain audibly present today.

Cardew's approach to graphic notation (informed in part by his performances with AMM) represented another way, a merging of elements from both traditions while also including other aesthetic considerations. *Treatise* put forward a new way of addressing improvisation with its graphic structures:

> What I composed in this piece – the image that hovered in front of my mind's eye – was a 'Musizierweise' (mode of music-making). I invented a way of making music and limited it to such an extent that musicians without construction ideas of their own are in a position to adopt this Musizierweise.

> I compose systems. Sounds and potential sounds are around us all the time – they're all over. What you can do is to insert your logical construct into this seething mass – a system that enables some of it to become audible. That's why it's such an orgiastic experience to improvise – instead of composing a system to project into all this chaotic potential, you simply put yourself in there (you too are a system of sorts after all) and see what action that suicidal deed precipitates (Cardew cited in Tilbury: 1983)

Cardew's conceptual ideas regarding *Treatise* along with the ideas of emotion and performer presence I discussed earlier set him (and the members of the British school) apart from earlier approaches. Understanding the graphic score as a system whereby the presence of all performers are amplified, increased and made evident allows us to distinguish it from systems such as the harmonic sets of structural constraints (as in jazz emerging from the post-bop traditions), or a randomly generated set of circumstances into which the performers 'insert' themselves (as in the chance aspects of indeterminacy). If emotion is a valid aesthetic position for the creative endeavour, then a much higher degree of freedom allowing for broader agency in the performer is possible.

By contrast, integral serialism is characterised by the absence of the presence of the performer (or by a negligible place for their presence).[20] One could argue that a similar absence of the presence of the performer is created by the chance elements inherent in aleatoric works or by the processes required to navigate the complex harmonic constraints of modern jazz. These both would inhibit the levels of individual presence that the British school desired. Cardew's invitation to the performer-improviser is: "insert your logical construct". This opens the way for practitioners of all genres of music, and those who approach improvisation in a variety of ways, to find a useful and fertile structure within the pages of *Treatise.* Aleatoricism and jazz are welcomed in *Treatise,* but neither is considered for inclusion at the expense of other possibilities. Cardew's biographer John Tilbury says of the composer:

> With him 'indeterminacy' was not simply another compositional technique, displacing a previously discredited one, it was a logical musical expression of his humanism: humanism is the vital thread that runs through all his musical activities, making for a continuity that overrides even the most radical stylistic changes in his work. His rejection of total serialism freed him as a composer; with his espousal of indeterminacy, creative freedom was also extended to the performer (1983:1).

I have chosen to discuss at some length the theories underlying the period of *Treatise*'s composition as it is still regularly performed by classical musicians, jazz musicians and avant-rock groups some of whose multi-genre work is musically comparable to some of the outcomes of my own creative work in this project. Additionally some of the first concerts using the cyber-guitar system employed approaches inspired by Cardew's visual presentation for composition (which I discuss later on).

The shape and design of *Treatise* can be compared to "the constructivist paintings of Kasimir Malevich, the lines, angles and circles that make up the score for Cardew's massive *Treatise*

[20] Theodore Adorno famously compared serialism to a type of political totalitarianism. See *Adorno on Music* (Witkin 2013: 139).

(1963-67) are designed to produce ... in the reader, without any sound, something analogous to the experience of music' (Cox, 2010:187). The score of *Treatise* itself seems to visually conjure up a memory of music previously heard, although not a specific composition *per se*, which would be limiting and contrary to the composer's intentions. It is, therefore, rather a feeling, or a visual reminder.

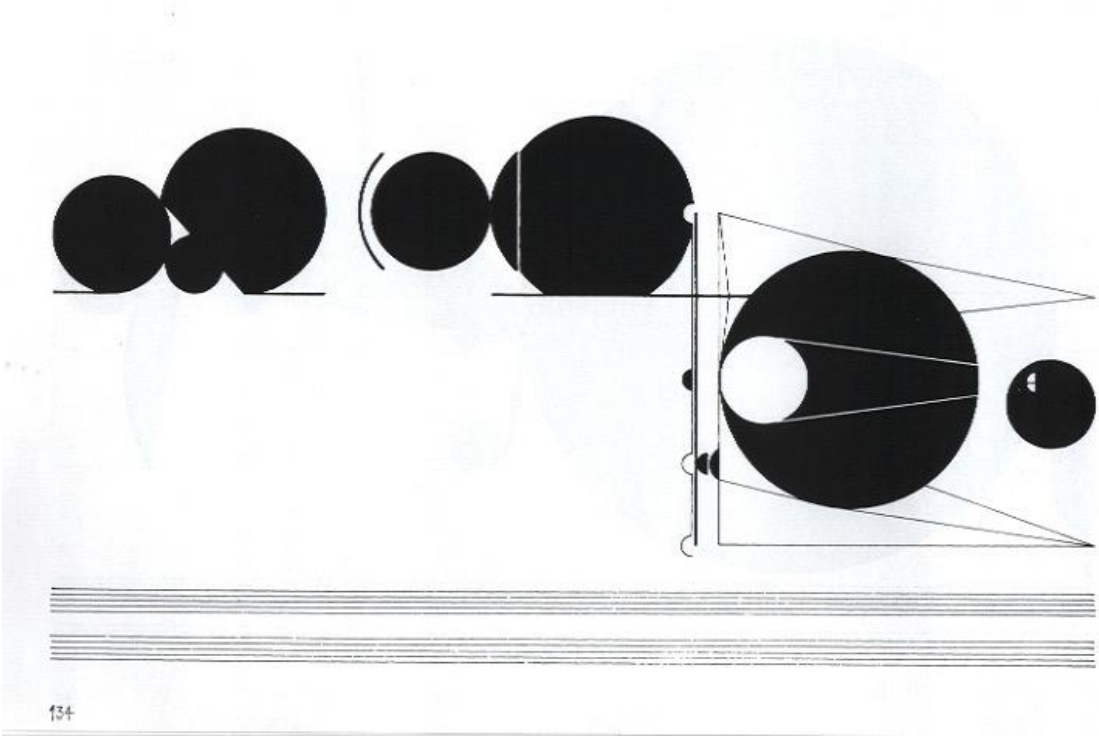

Figure 2: Extract from Cornelius Cardew, *Treatise* (1967:134).

In this notation (such as in figures 2 and 3) direct causality between symbol and sound is less evident. Rather, visual representation motivates much of the musical creation itself. Cardew argued that a "composer who hears sounds will try to find a notation for sounds. One who has ideas will find one that expresses his ideas, leaving their interpretation free, in confidence that his ideas have been accurately and concisely notated" (in Jenkins, 2004:xxxi). It is clear that Cardew imagines the performer to be an uninhibited realiser of the graphic score, sonifying the material imagined, improvised out of visual stimulus of the score, conceived as a memory of music yet to be realised with visual form as an impetus.

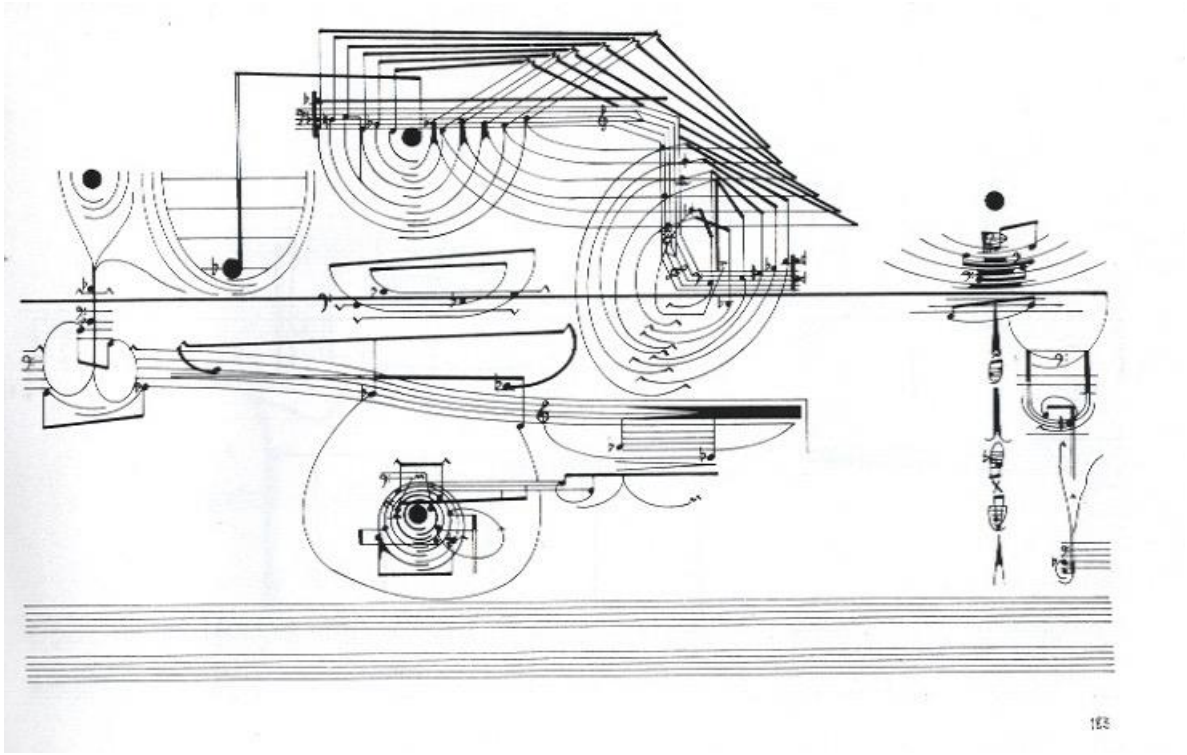

Figure 3: Extract from Cornelius Cardew, *Treatise* (1967:183).

On the influence of notation on the cyber-guitar design

I presented several concert performances during the phases of the cyber-guitar's development. As part of these various performances different musical texts, some existing and some original compositions, were explored as a testing of their use for and effect on the system, and I selected different graphic scores in order to explore different techniques that their compositions employ. The performances were group improvisations and used both specific graphic and standard notational approaches within small and large concert presentations to diverse audiences. Informed by my review of literature on notation I chose to use existing and original compositions that emerged as influential to my own project. These included works by Cardew, Morton Feldman and others mentioned thus far. In Feldman's graphic score for *De Kooning* (see fig. 4) minimal structural procedures are presented, with

single notes moving between instruments joined only by lines.[21] Performances of *De Kooning* tend to be exceptionally quiet and slow. The performance notes refer to the extremely quiet needs of the composition with instruments waiting for the previous instrument's sound/s to completely fade before making any sound of their own.

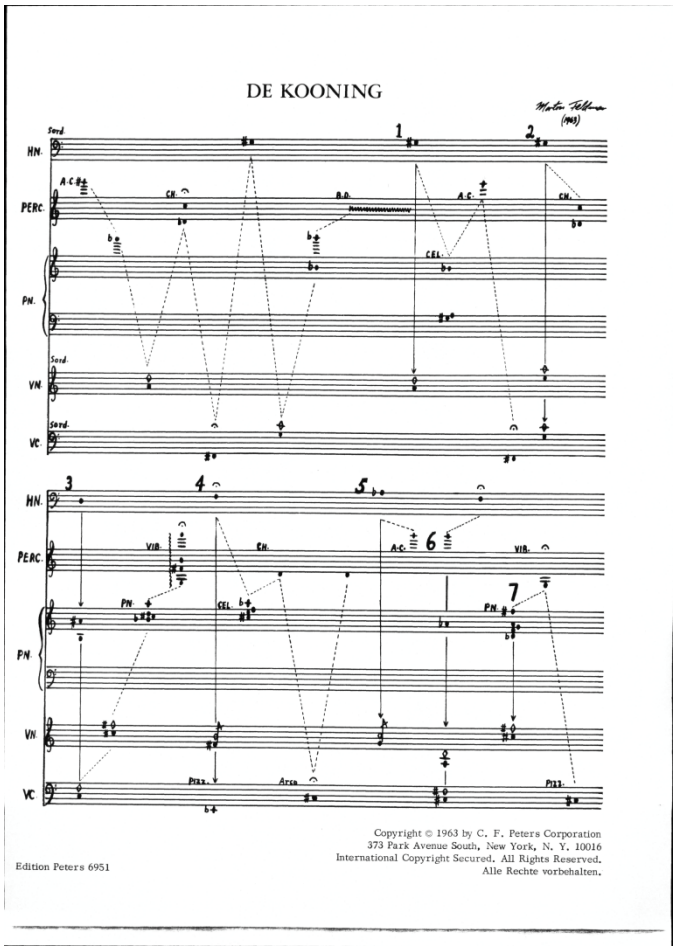

Figure 4: Full score of Morton Feldman, *De Kooning* (1963).

The visual 'look' of the score can reveal to performers elements 'as yet unheard'. We experienced this when Feldman's music was performed on the cyber-guitar system. Even given the capacity of the cyber-guitar to produce loud noises and erratic effects, and the fact

[21] The visual nature of this composition was useful to me when composing the final work *Hymnus* for the cyber-guitar recital. The visual presentation of pitched material is something that was integrated into section 3 of this composition.

that we used full amplification with live drums when we toured, the nightly performances of Feldman's *Intermission 6* (in the Czech Republic in November and December 2013) were consistently quiet and reflective. Although the same ensemble played nightly with this material the concert circumstances were vastly different from one evening to the next and this then provided a broad experiential pool for reflection. It did not matter whether the venue was a concert hall or loud pub environment: the work refused a dynamically loud result. The open spacious nature of the partially graphic score yielded a specific sonic product as performed by our ensemble despite there being no structural or dynamic indications for this on the version presented to the ensemble see fig. 5).[22] The specific visual approach evident in the layout of Feldman's *Intermission 6* was used in the Technologically Enabled Performance Practice (T.E.P.P.) recital score, *Hymus Caesus Obcessiones* and can be heard in the accompanying DVD in chapter four.

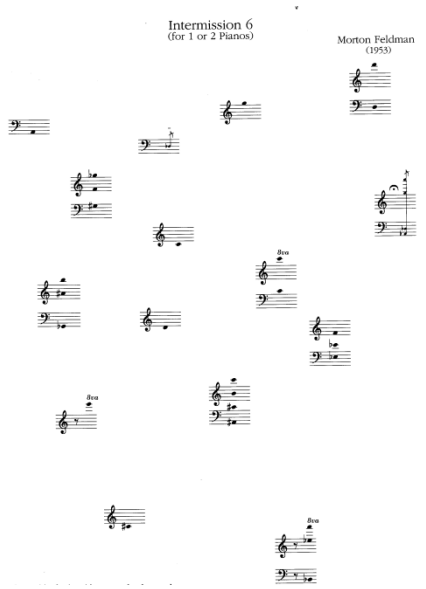

Figure 5: Full score of Morton Feldman, *Intermission 6* (1953).

[22] The original work includes specific performance instructions, but these were not presented to the other members of the group. Of course one could argue that as I was aware of the instructions I may have 'projected' them through musical choices I made during the performances. However, there are elements in the visual presentation that I have subsequently used in other circumstances which yield similar results. My goal here is not absolute empirical comparison, but rather general reflection on the processes and experiences that led to the graphic score for the culminating concert presentation of the cyber-guitar system.

Score elements were explored in the context of using the cyber-guitar system in performance. For example, in the first concert performance using the cyber-guitar (*What if the machines spoke back to you?*) in 2011 a simple line drawing was given to the performers.

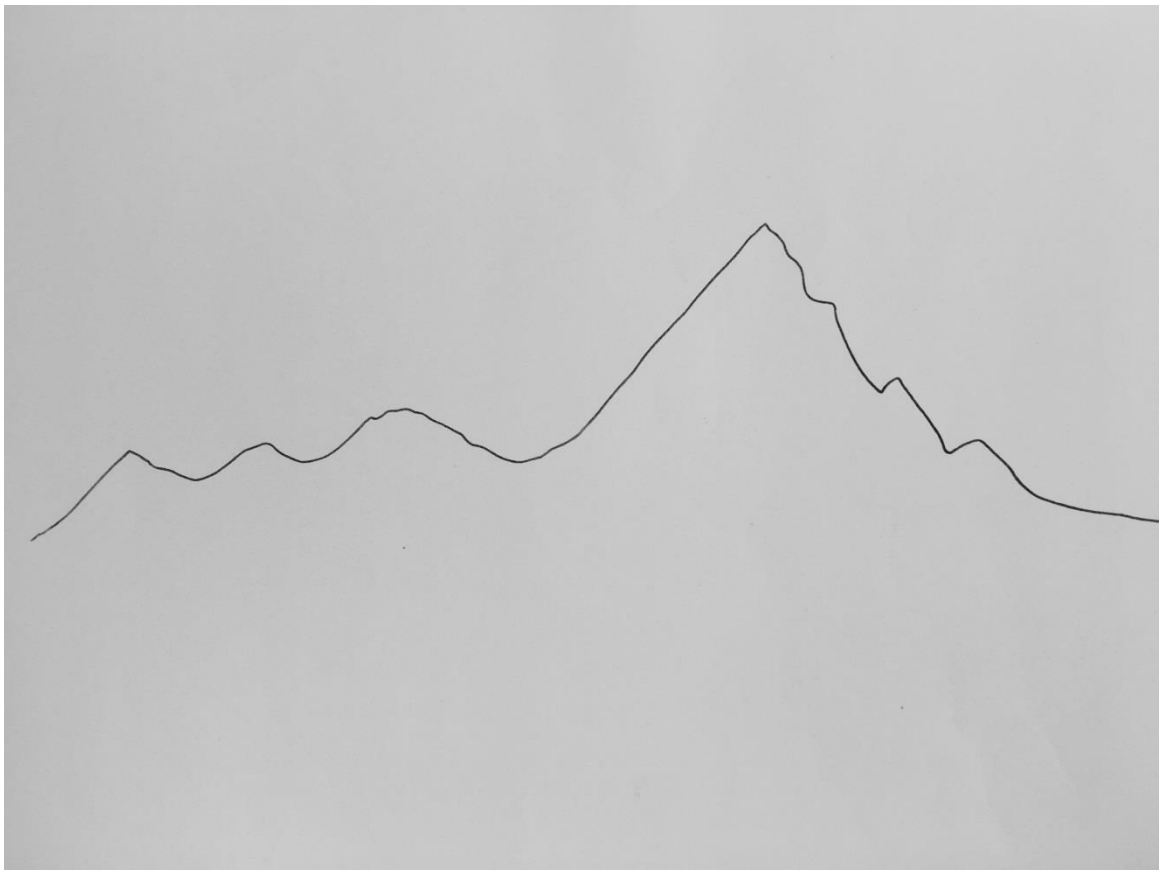

Figure 6: Score from the performance *What if the machines spoke back to you?*

The score indicated the duration of the performance and the movement of the line was intended to represent some sort of sonic density. I did not specify to the performers what aspect of sound should be made denser, and in fact I discouraged deciding on this prior to the performance. The only limitation given to the interpretation of the score was that the entire performance should last between 45 and 60 minutes. Regardless of the freedom suggested by the lack of clear instruction the drummer for this performance, Justin Badenhorst, recalled in the questionnaire on the concert I gave the musicians that he felt that the score "affected the performance in the way of directing a general intensity or direction of a free improvised conversation between Cyber-guitar, drums and electronics".

Works and their graphic scores were specifically chosen for their varying potential attributes including, for example, the spacious nature of the score in *Intermission 6,* and comic-design material of Cathy Berberian's *Stripsody* (see fig. 7).

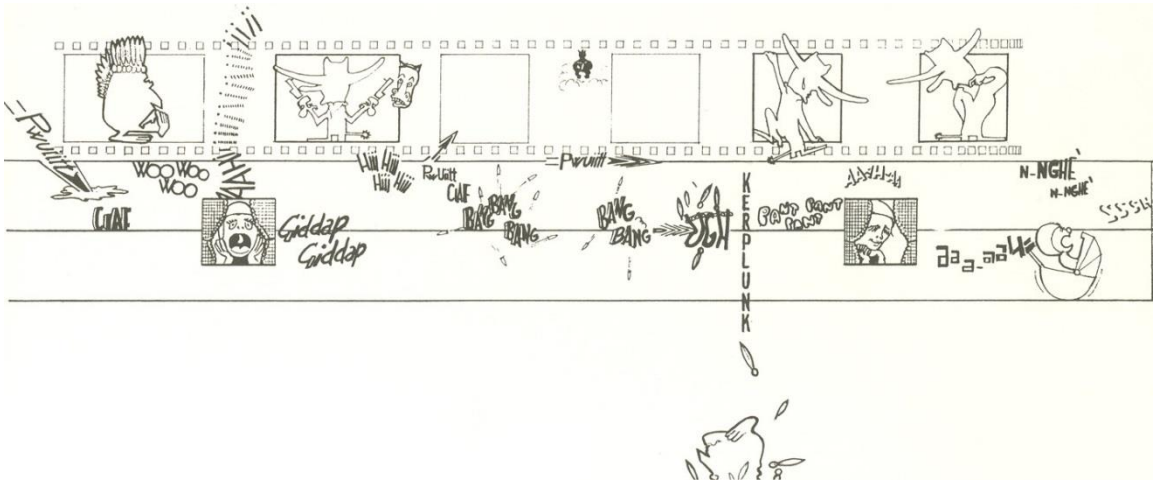

Figure 7: Excerpt from Cathy Berberian, *Stripsody* (1966:11).

By using a wide variety of scores (and the absence thereof) the collaborating performers were encouraged to engage in ways that may have been creatively unfamiliar to them and, further, be free to perform in ways that I would not necessarily have initiated under my own existing improvisatory impulse. In these group performances, where the ensemble improvised around graphic scores, elements appeared to recur. For example, as mentioned, *Intermission 6* by Feldman was consistently rendered softly, even when I attempted to entice the band to play louder. The score seemed, within this limited set of concerts, to influence the musicians' interpretations in a consistent manner, to a degree. *Intermission 6* was one of a variety of scores used, including *De Kooning* as well as a selection of jazz standards and works by the grunge rock band Nirvana, that were used during the late 2013 tour of the Czech Republic and Slovakia with Jonno Sweetman on drums and Lukas Kytnar on bass.

On this particular tour the range of scores created a reciprocal range of expressive engagements. Whilst, as noted above, certain scores yielded certain similarities in their rendering a broad and diverse range of materials yielded an equally broad range of engagements. When asked about the impact of the scores and the cyber-guitar on the group's performance Kytnar recalls, "I still now remember the adventurous improvisations which the band took on stages. The experience of this new aspect (the cyber-guitar) opened many new doors in each band member and pushed us to explore new, uncommon music lands during our shows no matter which style or tune we played together". If I had elected to use traditional scores over, for instance, graphic systems during these exploratory concerts I would have been concerned that the constraints which are components of the notation may have placed limits on the guitar's design. Whilst this assertion is empirically impossible to prove I do feel that the specific types of compositions and their notation allowed the cyber-guitar to explore a wide variety of musical avenues that may not have been freely possible otherwise. The freedom felt in graphic notation was in line with the freedom required to develop the instrument.

On Looping

As mentioned above during the cyber-guitars development the exploration of various graphic scores created performance outcomes that informed the design of the system. I had in the preceding years been increasingly engaged with technology in improvisational practice be these technologies signal effects or recording devices such as loopers. In 1999 I purchased a Lexicon Jam Man and spent many hours with it, using it as both a writing and improvisational tool. These experiments gave rise to compositions that were released on my album, 'Dreams of Skilia' on the FMR label in London in 2000.[23] By the late 2000's my use of looping devices had changed substantially, moving away from supporting or facilitating improvisational or compositional practice into using the devices to direct the creative process. In the Jonathan Crossley Electric Band loops were recorded live with intentional glitches so

[23] 'Dreams of Skilia' was released on FMR London in 2000 and featured all original compositions with Wessel van Rensburg on piano, and myself and Johnny Fourie on guitars.

as to create rhythmic figures that were erratic in nature. This new approach to the use of loops in part informed the ways of including technologies in the cyber-guitar construction. In the processes of this research project I desired to include the looping devices further by understanding the history of loop materials, in a more informed way and through this to create a clear method for their deployment in the system. As with notation by understating their history a little better I felt I could shape their use in the project in similarly more constructive ways.

The processes of tape looping emerged historically from research being done at Pierre Schaefer's Groupe de Reserches Musicales centre in Paris. Schaefer was experimenting with making circular loops on vinyl records, as opposed to spiral grooves (Zagorski-Thomas 2014:52) and it was here that Karlheinz Stockhausen (in 1952) first began experimenting with tape in a similar way (Holmes 2015:51). Later in the early 1960s looping as a procedure was being extensively explored and studied in centres such as GRM and the San Francisco Tape Music Center, headed up by Pauline Olivieros.

The use and application of looped materials in the types of experiments associated with these centres of research were focussed on the study of the nature of sound and processes emerging from this. They were not intrinsically focused on repetition as the current uses of looping technology, or in live-looping which in many ways derive their aesthetic history from minimalism. In the early 1960s the minimalist composer Terry Riley was just beginning to compose emerging out of his studies and was involved at this time with the San Francisco Tape Music Center, . His early works exhibit elements of his later style but it was only after his use of tape looping that the processes for which is he well known came to the fore (Sitsky 2002:393). *Three Legged Stool* and *Mescalin Mix* use the durations afforded by the tape loop to transform the perception of material. In 1963 Riley composed and recorded *The Gift* which was a recording of the Chet Baker Quintet performing Miles Davis' "So What". Riley used long tape delays to record the material and then was able to feed it back to the performers whilst the material kept recording and became thicker and more textural as the band played along to the loops (Sitsky 2002:393). Notably Riley and Steve Reich (in his early career) used tape looping extensively in their works and it is this use of tape looping that gave birth to

minimalism. However for the purposes of this study the application of looping stems historically from the work of Robert Fripp and Brian Eno. Eno introduced Fripp, the guitarist for legendary rock group King Crimson, to tape looping in late 1972 and the work that came from this interaction resulted in the album *The Heavenly Music Corporation* (Peter 2006:1). Fripp's use of this technology, which he named Frippertronics, is one of the first examples of a performer using live looping for musical creation in a single performer system. Fripp developed this system extensively during mid-1977 and began performing extensively with is in 1978 and 79 (Fripp in Mulhern 1986:1). The material it generated is textural in nature and this has been a defining quality of the use of live looping ever since.

Another key influence in my own understanding and application of loop usage has been guitarist David Torn. His work from the 1970s onwards is textual in nature and in his system design he is able to capture not only the sounds of his own instruments but those of the ensemble around him through microphones built into his guitars, a feature I copied in the cyber-guitar system. "My guitars have microphones built into them, and there's a room mic that feeds my mixer, so if I want to loop other people's stuff through my pedals, I just hit a momentary switch on my instrument, and they feed into whatever looping device I've chosen. When I'm playing guitar, my right hand is actually on the mixer about half the time" (Torn cited in Cleveland 2006:1). The current design of my own looping signal path captures the signals from the cyber-guitar in multiple ways, and this allows the user to record components of these loops. These can then be further modified by the worn exoskeleton component of the system.

Many contemporary musicians associated with the free tradition have used digital looping systems, integrating them into their improvisational practice. The resulting single loops are often fed back into the improvisation and alter the destination either of the individual musical invention or that of the group. Renowned saxophonist Evan Parker explains this as follows:

> I set up loops of stuff and then observe the loop and listen closely to the loop and say, ah, now I'll emphasize that note, or now I'll bring out that difference in tone, or I'll

> try and put something underneath it in relation to that or on top. Gradually the centre of attention in the loop shifts somewhere else. The loop suddenly is a different loop. It's something that's still bearing fruit for me. I'm not saying that's exclusively the method I'm using in solo playing but it's the core method (in Cox & Warner, 2010:243).

Here Parker refers to a solo process of recording a single loop and layering other material over this during an improvised performance. Parker's application sets up a type of feedback system between the loop and his saxophone improvisational. This differs from the conceptions of Torn or Fripp in that to improvise in this manner is to respond to materials in a linear way as opposed to texturally.

I consider my use of live looping within this project to have emerged from multiple areas – from composition, improvisation and sound technologies – that have informed my own practice as a musician. First, the aesthetics of looping in a group context are distinctly tied to aspects of musical creation that emerge from the use of recording in itself for in studio composition. As mentioned earlier Cutler's understanding of recording technology or in the studio creation is his third mode of production and this has impacted on the shape of this work. He argues,

> a personal vision is no longer the necessary mediator between composition and realisation. This can become a *collective* activity. Thus as a creative unit, the group finds the maximum of resources at its disposal in a recording studio – a medium which encourages collective work, and particularly collective composition. Where Jazz developed improvisation into a high art, recording allows its extension into composition (Cutler, 1991:35).

In other words, the recording studio, and recording technologies employed more broadly, may facilitate a process of group composition. It is a process in which collective compositions and improvisations are recorded for further review or fragments are recorded live and fed back into the improvisational process. Fragments of music can be assembled, re-

assembled, and/or edited together into larger wholes as the musicians involved assume the dual roles of composer and improviser.

Second, this process can be promoted by using a graphic score, amongst other things. For engagement with the recording studio, looping devices and related sound equipment demands little formal knowledge of music theory. Highly regarded artists such as Brian Eno are musically 'illiterate' in terms of reading standard notation. As Cutler proposes, "The argument in favour of working in and with the new media then is this: the old structure 'Art' music, that is to say music mediated by notation, is incapable of developing the aesthetic and productive power of the new productive media" (1991: 36-37). Certainly some musicians working within the recording tradition choose not to engage with notational materials at all, and some have also engaged in free improvisation practices. Renowned improviser Derek Bailey explains,

> The efforts in recent times to loosen the stranglehold that notation came to have on music came partly through a re-introduction of a certain amount of flexibility in the role of the performer, providing him with the possibility of affecting the creation of the music during its performance. Some of these developments, while removing some degree of control from the composer, have not necessarily introduced the possibility of improvisation (1992:60).

The developments in score innovation and technology have played joint parts in bringing improvisation back into wider musical practice. Interpreting works such as *Treatise* as a group improvisation in the recording studio has thus become a common occurrence – post-rock group Sonic Youth's interpretation of portions of *Treatise* comes to mind – and collective improvisation with looping devices is now commonplace.

The cyber-guitar system's loop signal paths used in live performances within group improvisation performances is a development of this lineage. The path is designed in such a way as to encourage a number of contingent practices. These include a loop system that is able to record immediate improvisations and play them back and also allows for additional

copies of the loop segment to be processed (in relation to tempo and pitch) and played back to the ensemble. In the cyber-guitar system the guitar itself allows for input into the 'guitar effects matrix' to come from either the guitar's pick-up system or through a microphone, which in turn allows ambient elements (such as the audio from the different ensemble players or even feedback) to be folded back into the front of the effects and loop matrices, creating contingencies that can affect the improvisational direction. I discuss the theoretical implications of contingency in the following chapter, and describe the design of the loop system more fully in the final chapter.

Hymnus Caesus Obcessiones

The score, titled *Hymnus*, created for the culminating performance of this project which took place in March of 2014 aimed to bring together elements of the compositions and performances that had been most usefully explored in previous concerts (some of which I discussed above) in order to employ them in an extended performance. The goal was to explore how the individual elements could be interlinked in as many possible ways within the instrument and performance system in order to yield the largest variety of materials and results in concert. The original graphic score (reproduced in figure 6) was considered to present enough relevant material to yield a coherent performance, whilst at the same time encouraging maximum musical freedom within the constraints imposed by a clock that gave specific time markers for each section. This score was a conglomeration of the various aspects of the previous test scores that were selected based on those that yielded the most eventful results and, although timed, still allowed the performers to interpret the images in the spirit of Cardew. Responding to questions I posed to the musicians who took part in the *Hymnus* performance bassist Carlo Mombelli recalls the impact of the score on the performance:

> For me the score did use some conventional music language just written differently. We had to follow the dynamics, the intensity and the silent pauses just like we would on a conventional score. The difference being that we were able to choose how we wanted to do it.

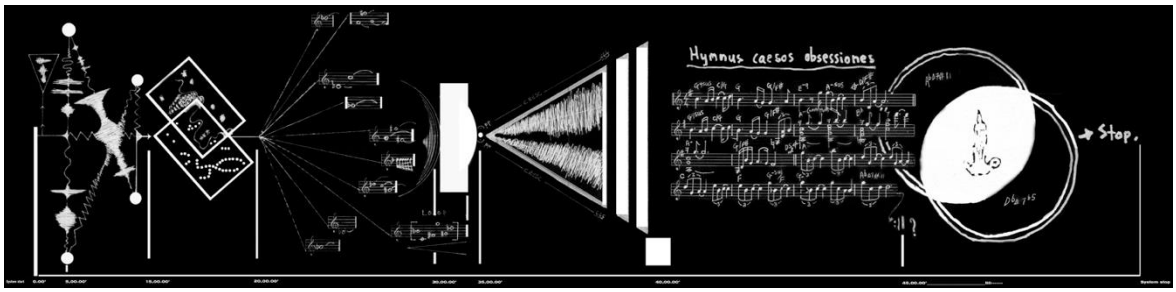

Figure 8: The graphic score of *Hymus Caesus Obcessiones*.

The score was projected onto the back of the stage and was visible to the three performers (two drummers and a bass player) who collaborated with me and who were located on three different stages throughout the theatre, whilst I, performing on the cyber-guitar, was on stage and able to view the score from an independent screen. The different parts of the score, as seen in figures 7 to 12, were varied in their representations. They ranged from hand drawings of audio wav file renditions from a digital audio workstation (DAW) as in figure 1, to score-based material as in Mortan Feldman's *Intermission* series. There was a time limitation to the entire performance with fixed durations per section that equated to the different visual segments of the score. A clock was set to count down so that the performers knew where they were in the score. Whilst entry and exit points were not indicated on the score, suggested entries and exists were chosen collectively through a preconcert discussion of the score by the musicians involved. This discussion was initiated by the group as in pre-concert discussion the need was felt for this to be specified. Interestingly the drummers chose to abandon these entries and exit points during the actual performance. Carlo Mombelli recalled this as follows:

> In the TEPP [technologically enhanced performance practice] recital I felt we could have entered the music better from a point of silence inspired by the sound of the cyber guitar as we had discussed we would do that. Instead both drummers entered the music conversation without listening to the questions I was hoping to receive first from the cyber guitar. However, in improvisation one needs to move with the flow of the conversation and yes it started differently, but it was perfectly fine to move in that direction. It worked.

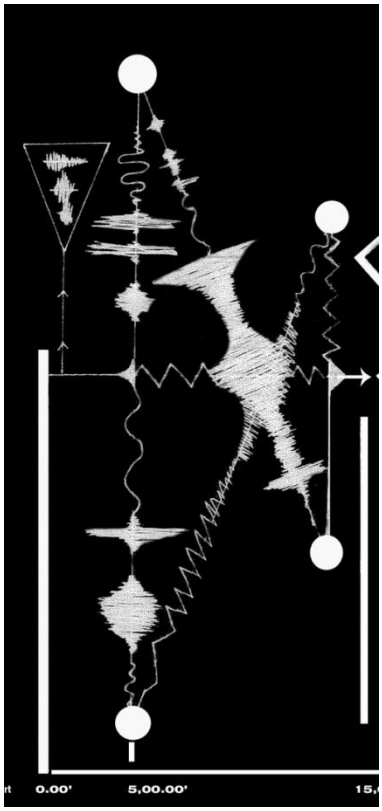

Figure 9: Section 1 and 2 of *Hymnus* (chapters 1 and 2 on the accompanying DVD, The Cyber-Guitar Recital).

The section illustrated in figure 9 covers the time area from zero to five minutes and five to fifteen minutes. Figure 10 shows the pictorial notation for the section between fifteen and twenty minutes. The initial five minutes were guided by a pre-performance discussion amongst the musicians, and it was agreed the musical material used would be sparse. At the five-minute mark the performers were given the option to follow the vertical line either upwards or downwards or, alternatively, to continue straight. At a visually estimated ten-minute mark the lines intersect again and the same option is offered to the musicians. Just before the fifteen-minute mark the lines – and potentially the performers' sound – unify creating a transition to the next material. As mentioned earlier this type of graphic material was explored in the first concert in 2011 at the University of the Witwatersrand given with the cyber-guitar system, *What if the machines spoke back to you?* The material used in the *Hymnus* score was more detailed, as the increased visual stimulus seemed, through our experiences in prior performances, to encourage more varied creativity.

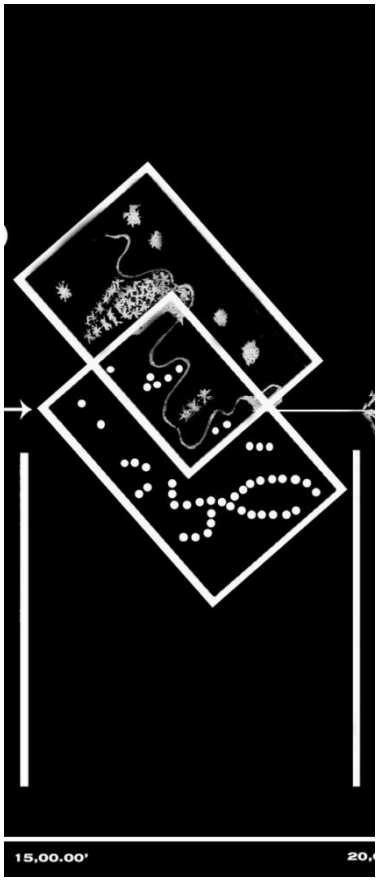

Figure 10: Section 3 of *Hymnus* (chapter 3 on the accompanying DVD, The Cyber-Guitar Recital).

In preceding concerts concepts from circular imagery in abstract art were also explored. This was done in two ways: through showing the musicians visual artworks (similar to, for example, Kandinsky's *Several Circles* (1926) and *Circles in a Circle* (1923)) as a stimulus or, on other occasions, through improvising without such visual material where the music performed was similarly as sparse (in terms of the total number of notes), spread out (in terms of the distance between notes) and singular (as in the number of notes played by each instrument at a time). Through drawing on these performances, the part of the score represented in figure 10 was composed. Over repeated events, this type of musical material seemed to encourage the use of silence and surprise, and also highlighted the ways the audio would interact with the various delay and reverb processes because of these moments of silence.

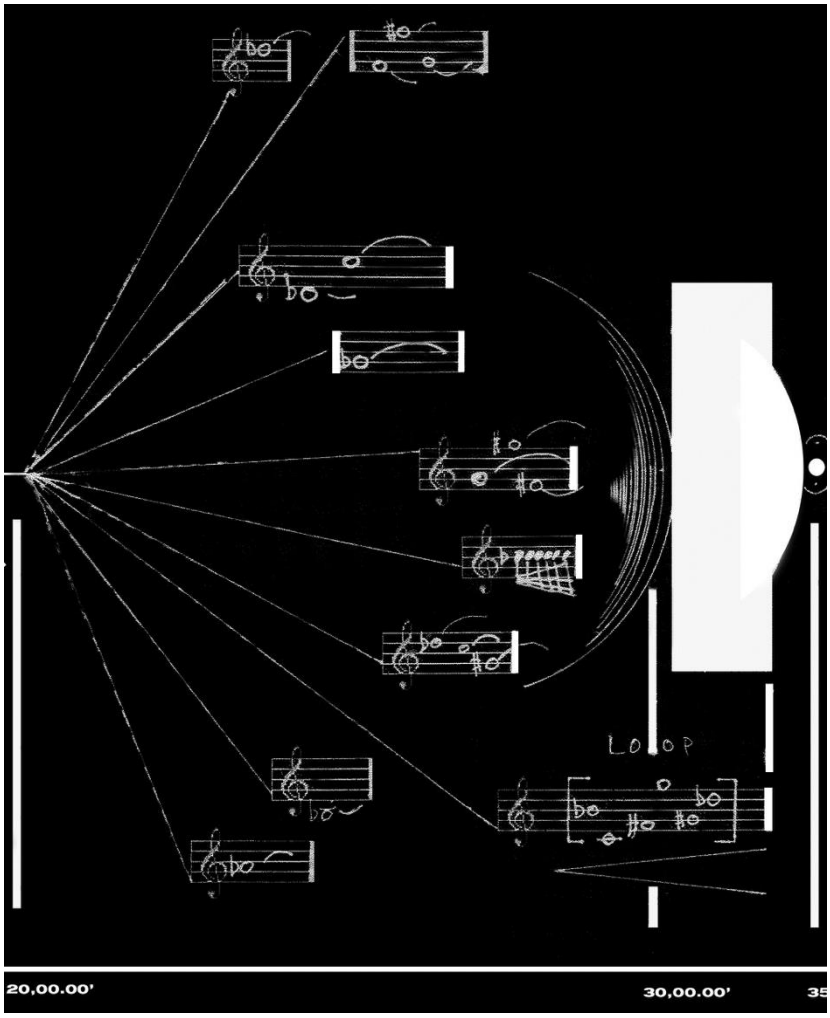

Figure 11: Sections 4 and 5 of *Hymnus* (chapters 4 and 5 on the accompanying DVD, The Cyber-Guitar Recital).

The segment between twenty and thirty minutes employs the notational approach taken from Feldman's *Intermission 6* and similar works. The notable differences are the radiating lines which steer the eye quickly to the staff notation-score elements. They also have a dynamic implication not present visually in Feldman's work with the length of the line seeming to affect (through observation over repeated performances) the performers' dynamic approach. Consistently it seemed that the longer the line the louder the dynamic result would be.

When approaching the thirty-minute mark the performers are visually drawn into unity by the crescent structure and then interact with the large solid object at thirty minutes. One

performer was given the option of repeating the loop fragment below the large sound mass, as a means to create a repetitive element against the higher dynamic. This was a useful way to link the two sections as, through experience, I chose to have certain repetitive elements sounding simultaneously with large amorphous elements as a matter of taste.

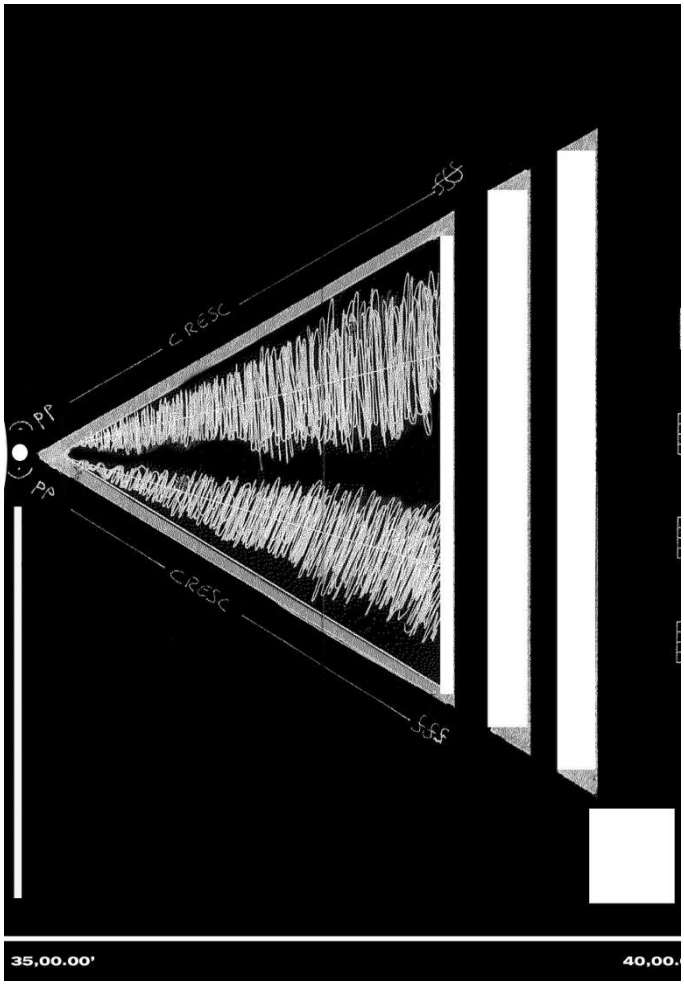

Figure 12: Section 6 of *Hymnus* (chapter 6 on the accompanying DVD, The Cyber-Guitar Recital).

The segment shown in figure 12 indicates a continually increasing dynamic texture alongside an implied increasingly dense visual event, with two 'empty' segments around two thirds of the way through the section potentially implying breaks in the sound. In earlier performances with the system it was shown that when performers were given a single, unbroken visual (in this instance a triangle, but single lines of linear and non-linear shapes were also explored) that increased in size, the dynamic and density stopped increasing just prior to the end of the

material, as if a sonic threshold was reached. This may have been due to aural, psychological or physical fatigue, or a combination thereof. However I found that by inserting breaks in the material prior to the desired climax that the musicians could reach higher levels of final intensity and volume once given a pause, a breath. Whilst the greater majority of the visual material was left completely open to the performers' interpretation I desired selected components of the score to be realised in specific ways to delineate the various segments of the work. The large square block prior to the forty-minute mark was encouraged in a pre-performance briefing to be lower pitched yet dense material as a transition to the segment to follow.

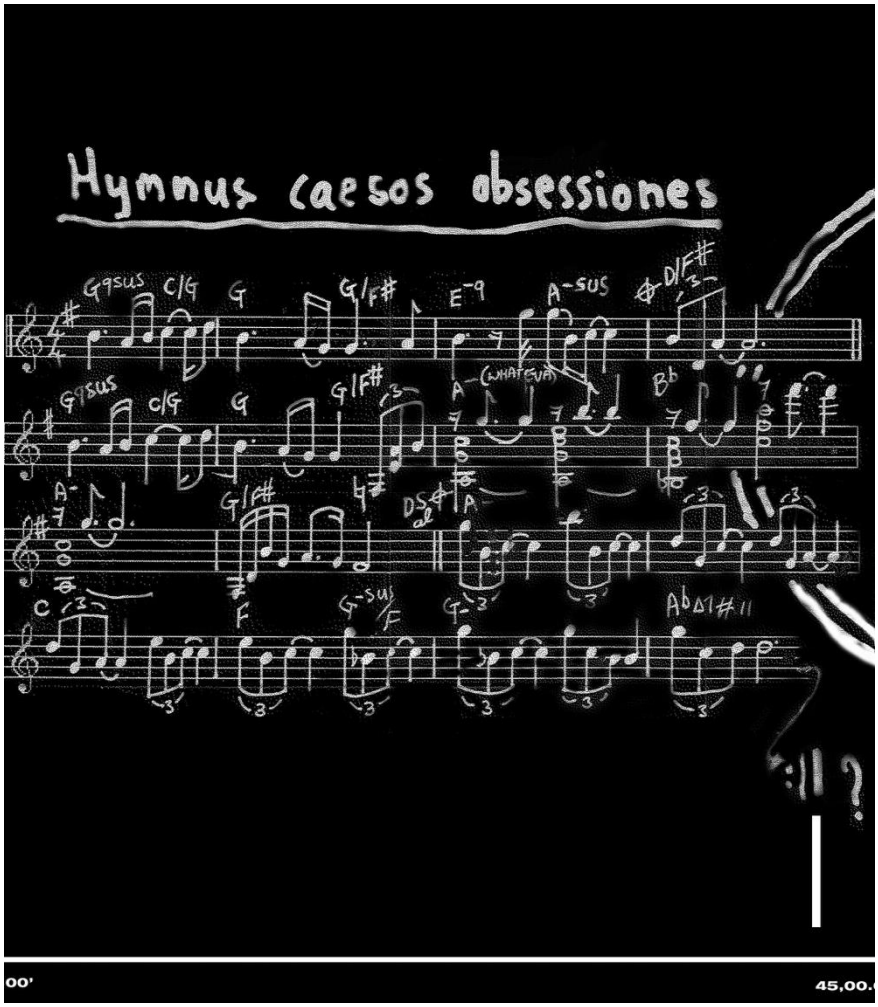

Figure 13: Section 7 of *Hymnus* (chapter 7 on the accompanying DVD, The Cyber-Guitar Recital).

The theme *Hymn for ceaseless obsessions*, after which the larger work is named, was a short melodic fragment I specifically composed for the recital. At an earlier performance in November 2013 material sonically similar to section 7 (although not graphically represented as in the *Hymnus* score) was presented. Then the only instruction in the timeline was that, after the sonically dense section, the group should improvise in a self-reflective manner. I did not specify the quality of this moment as it would emerge from the preceding section. This proved to affect both the musicians and audience emotionally. Perhaps the prayerful nature of the concluding improvisation amplified by the sonic violence that preceded it elicited this. Personally, and this accords with the views of AMM discussed earlier, I consider emotion to be a particularly significant improvisational element.

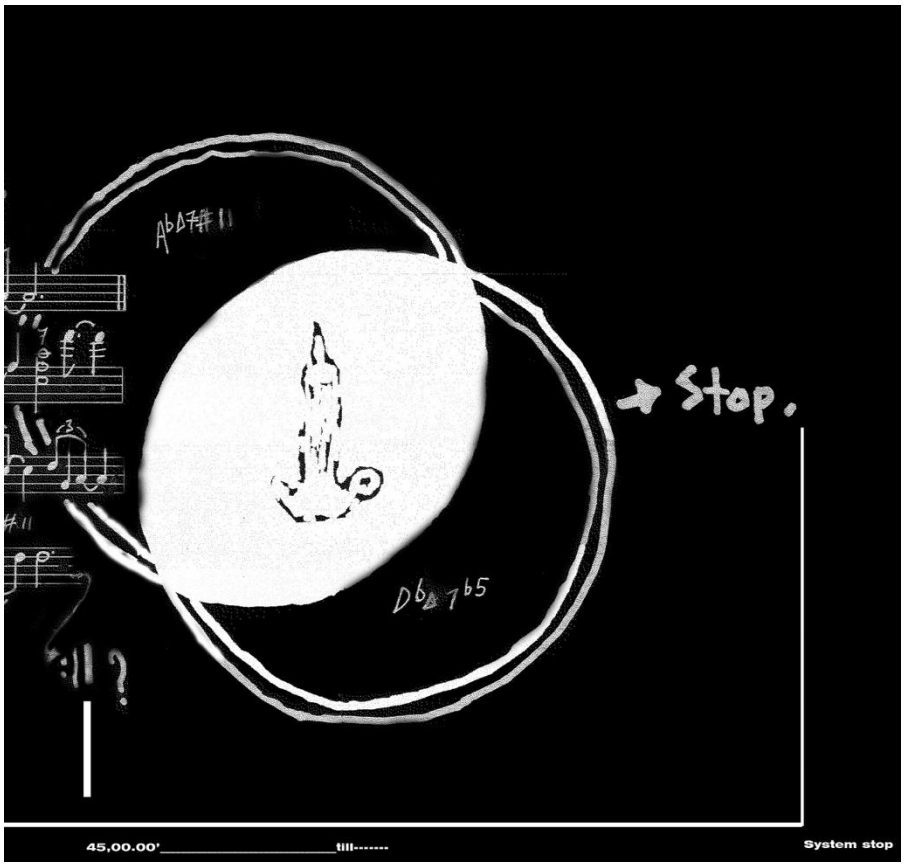

Figure 14: Section 8 of *Hymnus* (chapter 7 on the accompanying DVD, The Cyber-Guitar Recital).

The final segment of the *Hymnus* score sought to afford music that would draw the audience into an acoustic reflection of the total performance. The two simple harmonic choices offered

to the performers – $A^{b\wedge7\#11}$ and $D^{b\wedge7b5}$ – were not prescriptive of the modality or tonality, and the crudely hand drawn candle further suggested a fading event. This image was affiliated with some implied associations of a hymn, thus inviting communal associations with the performance as well. The circles precede the end of the performance and the intention was for the sound to break away into digital and implied digital noise signalling the end of the event. These suggestions were given to the musicians prior to the performance. During the pre-concert discussion the group offered suggestions for interpretations of the images contained in the graphic score that were experienced as collectively exciting whilst not being prescriptive. In both this final segment and the penultimate section I chose to draw the images by hand (imperfectly and informally, with an innocence that deconstructs the authority of 'the composer'). During the test performances these hand-drawn images seemed to invite a more open and playful engagement with the score as if further breaking down the authority inherent in the narrative of a 'perfect', 'complete', and formalised score.

Carlo Mombelli noted the following regarding the variable nature of the score in this performance:

> The score did affect the performance however I was able to improvise and have a debate when spaces were given. What I did like about the score was that if I saw a symbol I was still given the freedom to interpret the music my way.

***

David Toop reflects on the intersection of the technological and notational elements I have discussed thus far:

> some of the core issues challenged by the advent of 20th century music, and 20th century thought in general: the relationship of the composer to the audience, for example, or the use of chance and accident in the creation of music; the construction of feedback systems or self-generating and adaptive mechanisms that shape sound; the exertion or abdication of control of a musical result; the modelling of music based on ecosystems and similar complex environments and the setting in motion of events that question the definition of music as a

> cultural production distinguished from noise or unorganized sound by human agency and intentionality (in Cox and Warner, 2010:240).

Many performance systems, performances and compositions in contemporary musical practice deal with one or more of the areas outlined by Toop. The cyber-guitar system and the extended PA system engaged with many of these areas, and the intention was to do so in a holistic manner. One of the principle goals of the project was that by the time of the *Hymnus* concert the performers could engage the greater system in a similar way to how one would engage an individual instrument, with the system being conceived as inclusive of all the notational and technological elements that characterised its makeup and functioning. These include not only the instruments but the speaker systems (monitoring and front of house) as well as the cyber-guitar, looping devices and all the technologies used by all individuals. As new musical instruments generate novel sets of performance practices, the cyber-guitar system engenders new musical possibilities. The possibilities that emerged are discussed in subsequent chapters; and the entire system is so designed – it is open and exploratory, and its development ongoing – such that new possibilities continue to unfold beyond the boundaries of this research project.

Furthermore, the *Hymnus* composition and compositions for performances since then have aimed to extend the scope of the system. In the *Hymnus* concert this was attempted by adding quadrophonic spatial dispersion of sound and by matching this visually with the placement of musicians.[24] When questioned about the multiple stages drummer Badenhorst remembers this spatial dispersion affecting his performance: "These elements created interest in my performance, as it felt like I was communicating with different stages at any given point, but dictated by the Cyber-guitar, creating interesting overlaps of musical topics which were sometimes disconnected, and sometimes spontaneously complimentary".

[24] On the DVD recording of the performance, *The Cyber-guitar recital, Hymnus* (see Appendix A) one can track the score with the sound result although at the performance this was difficult for audience members given the location of the four stages. I chose to have the concert spread across four stages in quadraphonic set up and I note, retrospectively, that this may have hampered audience engagement. Audience members' gazes shifted continuously and this made tracking the score more difficult. However, the DVD editing process has allowed the highlighting of elements of engagement with the music in a clearer way for the viewer.

This thesis reflects on a personal explorative process. The current chapter examines how *Hymnus*, the work for the culminating performance of this research project, functioned as a score in performance, with my intention being to situate it within a historical context of notational and improvisational development, as well as how it reflects a converging of the development of my own performance and compositional processes. The chapter that follows also considers how the development of the cyber-guitar system paralleled my unfolding relationship with notation and improvisation, but through a different lens: the struggle to define my relationship to noise and music.

Chapter 2

Noise, Music and the Creative Boundary

Introduction

In this chapter I discuss how I grappled with the function of noise within creative practice as I experienced it through the cyber-guitar project. The subject of noise, for me, was a sonic (rather than social or political) one at the outset. The system's complexity meant that the experience of 'trying' to play the enhanced guitar involved navigating a field of initially unmanageable sonic errors. As a performer one is taught to aspire towards perfection in execution, and new musical events are to be mastered by repetition. I found myself overwhelmed, at least initially, as I tried with difficulty to master the system because of the scale of the design of the cyber-guitar and its exoskeleton, while desiring to continually test the system in performance. However, the quest for mastery gradually fell away and was replaced by a fascination with the potentialities that were presented by the guitar. This situation led me to question: what is noise in this context? The quest to exclude noise, as I initially sought to, may not be as creatively fruitful as engaging with it as a creative endeavour.

In digital technologies, whether CD audio or the computer on which this thesis is being written, noise – as error – is present. Due to error correction, though, the noise is no longer (as) perceptible to us. In analogue computing this almost derailed the development of computation until Claude Shannon's (1948) landmark research. Shannon proposed that whilst errors (as noise) in calculations were present these could be reduced through replication (in von Neumann, 2012:12). If a process was recreated a certain number of times then the correct, or perfect, result could be chosen by considering the volume of mathematically correct results against the volume of incorrect results. As the mathematically correct results outweigh the incorrect ones, the incorrect ones are consigned to noise and not considered (Kurzweill in von Neumman, 2012:12). This process of error correction is present in all of our contemporary technological experiences. Ray Kurzweill reminds us:

> Older readers will recall telephone modems that transmitted information through noisy analogue phone lines, which included audible hisses and pops and many other forms of distortion, but nonetheless were able to transmit digital data with very high accuracy rates, thanks to Shannon's noisy-channel theorem. The same issue and the same solution exist for digital memory. Ever wonder how CDs, DVDs and program disks continue to provide reliable results even after the disk has been dropped on the floor and scratched? Again, we can thank Shannon (in Von Neumann, 2012:15).

Through Shannon's theorem the mathematical errors (noise) in computer calculations can then be excluded. I am interested not in the gradual exclusion of noise (as in the removal of error), but rather in investigating the value of the event in trying to engage with noise in the moment. My focus is on allowing the event to invade the creative moment because in this way we invite the unexpected to propel us in potentially new, not yet imagined directions.

Interestingly, Kurweill also refers to the process of noise being introduced through the use of analogue tape for recording. Through the process of recording onto and later the copying of tape, tape hiss was gradually introduced. This was a sound confined to noise at the time. According to Kurweill, "There was noticeable degradation on the first copy, for it was a little noisier than the original ('noise' represents random inaccuracies). A copy of the copy was noisier still, and by the tenth generation, the copy was almost entirely noise" (in Von Neumann, 2012:13). When considering tape hiss one might argue that not all noise removal is desirable. In fact, "the term 'lo-fi' appears more often as a descriptor of a desired sound than of an undesirable quality" (Stuhl, 2013:42). When compact discs arrived on the market audiophiles lamented their coldness, due in part to the perceived absence of hiss or noise as these elements had come to be associated with an aesthetic worth that was audible on older sound reproduction technologies such as record and tape. The aesthetic value of this type of noise was ascribed only after it was made absent, later becoming an aesthetic style in itself, as in the designation 'lo-fi'.

During the course of the current project I began to see the unexpected as a potentially valuable creative tool and the instance of its occurrence as a fertile place for novel interrogation. I, therefore, began to seek it out. Although I have thus far referred to noise as error, this is but one of many conceptualisations of the phenomenon. The project necessitated a thorough consideration of the notion of noise, from a number of theoretical perspectives, and in a manner that was useful for the cyber-guitar system's sonic practice.

Throughout the developmental stages of the project I have intentionally grappled with specific ideas relating to noise and notation in practice. The various performances utilising the cyber-guitar, which I describe in further detail below, were each different in design and intent. Through these performances I engaged with, for example, concepts of cybernetics and machine intervention, perspectives on noise, feedback loops and intentionally flawed systems, and issues of notation, including interrogating specific traditions of graphic notation and works which I addressed in the previous chapter. The performances and creative engagement with these ideas and practices affected the project outcomes and direction. This, in turn, impacted on design choices for the cyber-guitar system, both organologically and technologically, and further adaptations were made in light of musical and physical successes and failures during concerts. This often resulted in changes to the direction of the project and on-going modification of the goals for the system. I came to retain and deploy certain aspects of the system through following performances. The contingencies, flaws and events that I found most creatively stimulating were the ones that were unpredictable. The performances were thus not designed to be 'perfect' events in the classical performance tradition, but rather explorations that welcomed error as a field of enquiry and a stimulus for design. Rather than relegating the unexpected to the realm of 'flaw' in the conventional sense, the flaw became something productive.

Unpredictability can be understood in a practical musical sense as a contingency or event that can, through repeated exposure, be learned and thus subsumed into musical practice. Contingency for the purposes of this project is defined as an unexpected event, an occurrence that takes place outside the confines of an event's design, and can open developmental possibilities if considered. One could argue that the particular process of interfacing machine,

body, and music with one another, as explored in this research, fosters the invitation of elements that could be viewed traditionally as non-musical events. These events interrupt and misdirect the creative process and its flow and, as such, they could be considered as lying outside the accepted and conventional applications of musical performance technique.

Significantly the cyber-guitar system does this in a way that, I argue, is conceptually different from other types of musical or performance engagements with noise. Other composers and performers who have used noise, for example, Merzbow and Yellow Swans have taken it as material for sonic creation or have used the unfolding and development of noise as material. The specific approach to noise taken by this project does not consider it only as malleable sonic material, but through continual development and deployment, the system brings material into the improvisational realm during a performance. This does not take place through pre-recording or system-based generation, but locates the engagements with noise within the performers' improvisational language. As an improvising performer my engagement with noise is principally around using it as a creative stimulus, a motivator of 'in the moment' inquiry. It pushes the music in unexpected directions, fuelling the creative endeavour. The following section grapples with these issues more deeply in order to present a fuller understanding of noise in the context of its deployment in the cyber-guitar system.

The problem of observation

When discussing the division between noise and music a problem that is noted by many writers, including Simon Reynolds and John Cage (in Cox & Warner, 2010: 56), is the subjectivity of the listener. The problem of observation refers to the manner in which in the process of listening the notion of noise in itself dissolves. In part, observation is counterproductive to the process of trying to introduce noise as a conceptual element, or as a part of the compositional or improvisational practice. This is because by documenting an observation the event becomes repeatable and then falls beyond the realm of unexpected contingency or non-musical intervention. Noise is no longer 'noisy'.

In psychoanalytic psychology the conversion of the socially unacceptable into something acceptable was referred to by Freud (1930) as sublimation. In a similar manner, the conversion through observation of the noisy to the musical can also be considered to be a type of sublimation. When a noise element is subsumed into musical language it ceases, in that specific context, to be noise in itself as it is structurally sublimated into compositional narrative or performance practice.

This process of sublimation reveals itself in the techniques of notation throughout the twentieth century in terms of how they facilitate the continual inclusion of new elements; elements that were not originally part of standard musical language (Epstein, 2008:xvi). As discussed in the previous chapter the various scores I have found most useful to this project and my own compositional approaches have been ones that have had to tackle the inclusion of noise elements in their process of creation. Music can be understood to function as a continuously evolving language in that it involves a set of structures, rules, forms, and general conventions brought about through practice (Cross, 2002:2). Any new practice that introduces elements previously considered to be non-musical augments the existing language and vocabulary once these are appropriated. The 'new' is always consumed and brought into the language as soon as the intent to create something repeatable has been fulfilled. During the twentieth century the elements included or subsumed into musical languages grew at an unparalleled rate, absorbing aspects that, before explanation and categorisation, would not be considered as musical elements or expressions in themselves. Cutler's push towards addressing notation as a form of commodification supports this notion as well because the repeatable event becomes commodity and, thus, forms part of the standard practice of music itself (1995: 28).

The process of the sublimation of noise elements into musical material, as recorded through their inclusion in notation, has been a central aspect of the cyber-guitar project. As the noise element becomes an accepted part of standard musical practice, notation is expanded to accommodate and represent the new element for reproduction in performance. The question

in this chapter is not whether noise elements should be subsumed into practice, as they inevitably were from performance to performance, or whether noise is aesthetically valuable or not, but rather how one could remain within the process of exploration given the seemingly inevitable processes of sublimation. If both the addition of 'noisy' elements into music and their expression through notational practice result in a (new) canonical end then how is the concept of free improvisation or continued exploration maintained using noise? Could this disjunction not be an expression of the tension between the processes of noise inclusion and improvisation; and is the area of tension itself then not the most fruitful area of exploration?

Reynolds affirms this premise:

> The problem is that, to speak of noise, to give it attributes, to claim things for it, is immediately to shackle it with meaning again, to make it part of culture. If noise is where language ceases, then to describe it is to imprison it again with adjectives. To confer the status of value upon excess and extremism is to bring these things back within the pale of decency. So the rhetoricians of noise actually destroy the power they strive to celebrate; they are the very start of the process by which subversion is turned into contribution, which is absorbed as a renewal for the system (in Cox & Warner, 2010: 56).

I have continually strived to include the principle of contingency in the system and performance design from the initial developmental phases through to the building of the system components. The following section describes and elaborates on the approaches taken during the building process and a selection of 'test' performances.

Error as a design imperative

During the early build stages of the project (in the first half of 2012) I tried to include error, mistakes or contingencies through various hardware-hacked loop stations.[25] While the loop stations were unsuccessful as a component of the cyber-guitar due to modifications causing a complete failure of their systems, they remain an example of how the principle of contingency was conceived of as being central to the system. The modification of the hardware was an attempt to simultaneously record three identical phrases played on the cyber-guitar. I hoped that they would drift out of phase in a number of ways: through user intervention (both through pitch and tempo adjustments that were features available on one of the processors), and notably through chip drift by the inbuilt clock drifts inherent in the looping devices. The drift was never achieved in performance as it would have taken many hours for the drift to be audible and, thus, the machine intervention I imagined taking place in this way was not possible. I elaborate on the design concepts, successes and failures, and the physical build processes in chapter four.

I also explored other possibilities for inviting contingent elements into performances and rehearsals during the development of the instrument and system. These included routing three performers (playing guitar, bass and drums) through a computer running a specially designed session in the Logic audio DAW. The session was created by Jacob Israel, an electronic artist who assisted me in the early stages of the project for the two concerts *What if the machines spoke back to you?* (2011) and *What if the machines took control?* (2012) both held at the University of the Witwatersrand. Israel designed the signal routing for the performance. This session and its routing procedures were designed to go through a variety of software plug-ins that had 'randomised' values set to selected parameters, radically sculpting the audio in unpredictable ways. These 'randomised variables were pre-entered into Logic through random automation parameters that executed during playback across the duration of the performance. Whilst they didn't use a random software generator (such as available in MAX

[25] The pioneers of hardware-hacking are Rheed Ghazala (see, for example, *Circuit Bending: Build Your Own Alien instruments*, 2005) and Nicolas Collins (for example, *Hand Made Electronic Music: The Art of Hardware Hacking*, 2006).

MSP) they were unpredictable enough so as to effectively explore the aesthetic goals of the performance in question. The results of these changes were then fed back through monitors to the performers who then improvised with and were guided by the changes in the music.

The ongoing attempts at involving contingency provided an aesthetic frame throughout the project as well as influencing the specific conceptual approach to noise and the engagement with it. The system mentioned in the previous paragraph was conceived prior to the performance and was only set up and tested functionally on the day. The ensemble could, thus, not prepare for the performance and was instructed on the day not to 'rehearse' during the sound check. I desired to avoid the types of inter-musician familiarity that often occurs when freely improvising together which may inhibit the contingent (Walton, Richardson, Langland-Hassan, & Chemero, 2015:6).

The concerts *What if the machines spoke back to you?* (2011) and *What if the machines took control?* (2012) took place a year apart and their outcomes were quite different. In the first concert the overall contingency at play was so effective that at many points the three improvising performers (Justin Badenhorst on drums, Jacob Israel on electronics and myself on cyber-guitar) could not identify who was making the sounds that were fed back to the performers through the monitors. I often had to mute my guitar to establish what I was reacting to and what I was creating. Badenhorst is a skilled drummer and improviser in jazz and the sounds generated by both the cyber-guitar and machine system impacted his improvisational choices. In response to the questions I posed to him about this concert he explained that both the randomised audio system and the cyber-guitar "definitely influenced and impacted on my personal performance, as accompanying unconventional sounds etcetera from the Cyber-guitar opened up the element of creating unconventional communication from my more conventional/traditional analog set up".

The Logic session created a level of variability that had a significant impact on the outputted audio and the resulting improvisation in the concert. Every signal was routed through the randomised Logic audio session and, as a result, the levels of variation and density were

extremely high. This randomisation afforded the machine a high level of agency expressed through the improvisational manner in which the performers engaged with these randomisations. Whilst the use of the term agency implies sentiency this is a position adopted by the researcher within the context of group improvisation and the agency is conferred to the randomisation. During this concert the emergent material was generated by the system as the sound produced by each musician was 'fed' into the machine, 'partially digested' and 'regurgitated' in a modified, yet partly recognisable form. The sound produced was experienced as separate from (while still part of) the musicians and this gave the sensation of a musical presence with agency and although the signal modifications were not truly in response to the incoming audio the unpredictable nature of the signal modifications gave the illusion of agency.

It was challenging to analyse this performance afterwards, and it was difficult to process my personal experience. The musical process and product were unexpected and novel; the boundary between the audience and performers was unsettled because of the additional unknown, non-human presence of the machine; the audience response during and at the end of the performance was mixed with excitement, anxiety and uncertainty; our traditional sense of 'beginning' and 'ending' was disrupted and out of our control; and the stimulus for musical change was not a fellow human musician whose input (capacity, humanity, and psychology) one could comfortably anticipate, but a machine generating unexpected stimuli. At this early stage of the research I had neither the insight nor the processes of thinking to reflect constructively on these events, and perceived them somewhat negatively. However, after listening to the material and conducting further research and reflection my opinion shifted and I could think about the performance more objectively. I heard little in the music that seemed to be the recognisable playing of the performers whose individual work I was familiar with. Rather, these musical identities had been 'stripped away'. I realised that this had resulted in unconscious discomfort for me at the time. With distance and development however I became aware that this dissolving of the audible personal presence of the musicians was indeed evidence of the function of noise as contingency and noise as directive of the improvisation. The specifically designed Logic session had an agency of its own within the session and was experienced as a co-improviser with the ensemble.

Encouraged by the results of the previous concert I then conceived of the next performance *What if the machines took control?* as a continuation and expansion of the ideas that were emerging. Rather than having the session designed in the DAW responding to the audio initially provided by the performers, the system conceived of for this occasion was designed such that the performers should wait for audio to be provided by the DAW. The same type of randomised variables were introduced into the Logic session via audio effect plug-ins, but the musicians were instructed to respond to them only if there was sound initiated by the system. At the outset this heightened the synthetic presence in the performance process through the tension inherent in the design. What if, for instance, the random variables on the audio effect generated no sound as they were not mapped to synthesis devices? After all, they were relying on ambient noise of the concert environment or base-level noise of the systems to provide the audio for modification. How would the performers react to this, especially in the presence of an audience and the resulting obligatory need to perform?

For the second concert two additional performers joined in, bringing the ensemble to five musicians and the DAW. I chose not to use a score, rather electing to shift the task of initial musical creation to the DAW, which I imagined as a sort of artificial intelligence or lead improviser. These two decisions had interesting results, some obviously related to aesthetic goals of the concert and some unrelated. With the audience seated the instruction given to the performers on stage was to wait for a signal from the machine to which to react. The time spent waiting for the DAW to create audio materials with which to improvise, however, became too anxiety-provoking and the improvisers began to lead the concert, asserting dominance and negating the 'compositional' guidelines for the concert. At the time I felt concerned about the resulting performance, as the main aim for the concert, as announced in its title, had been subverted. I felt that the musicians had capitulated to their own desire to control the performance environment as they failed to wait for the machine to generate the sound. The experience was recalled differently by some of the performers involved, however. The bassist Carlo Mombelli recalls the experience in a similar way to me. He says:

> I did two of these concerts and I felt the second one in the Wits Theatre [the T.E.P.P. or cyber-guitar recital of *Hymnus*] as much better as the musicians were more in sync with one another. With this concert being one of the first in the series there were moments of uncertainty as we tried to create from point zero. I had a problem that sometimes some of us didn't listen deeply enough and sometimes it was forced or overplayed without any regards for silence, but in general it was a great success and that's the difference with a debate and a reading, you never know where the debate will take us.

Another collaborator on this concert recalls the situation differently. Joao Orccheia who played guitar as well as signal generating devices says:

> My memory of the concert is more weighted towards the musicians involved and the interaction with and between them. I remember an electronic element that we were to respond to, and it could be that some of the musicians were responding more directly to that "synthetic band leader", but I was responding more to the other musicians. Perhaps because in number and volume (amplitude) the human participants were more than the machine, I was far more aware of the human contingent.

Badenhorst however recalls the objective of following the machine as being successful (perhaps in part because he was involved in the preceding concert):

> The objective was definitely realised and collaborating with a purely digital/electronic system found me communicating with a different mind-set. The element of coincidence and free improvisation was on a much higher level, as I was responding to an element that had almost no boundaries or any form of predictability. My personal experience of the objective was very exciting, and forced me to play with absolutely no preconceived ideas at every point of the performance.

The recollections of the various performers reveal intervention that I had not expected. For Orecchia the individual performers were most prominent in guiding the direction of the

performance and thus he automatically leant towards a type of improvisational conversation with the musicians, even though the pre-concert instructions were clearly to let the machine lead. Because each of the performers (although not the machine) was known to him in a musical capacity he was familiar with their different approaches towards different types of improvisatory and musical styles. For him, this network of musical histories and relationships could have been emphasised more within the concert, because in his memory the machine was ancillary. He elaborates that the directive to follow the machines was not made clear enough in pre-concert discussions:

> In the choice of participants, each fairly weighted towards different aspects of the above. Knowing the musicians individually, it is clear that each would be open enough to find a place among the voice of the others. It may have been interesting to focus even more on this aspect by discussing it in advance and asking each participant to "try" to keep more or less to their "discipline" or style or voice in order to discover how this might affect the others within their respective styles.

The unexpected tensions experienced by the musicians towards the machine and concert's aims invited useful questions. For instance, was the way I directed the unfolding of the system noise element – the contingency – contrived? Whilst waiting for the input from the DAW may have been interesting as a development from the previous concert, the artistic nature of the endeavour may have been limited as it inhibited agency from the highly skilled performers on stage at the time. Also, surely my unexpected reaction (to the performers taking over from the machine) was facilitated by a type of noise, a contingency in itself. The 'failure' of the event was the contingent event, with the anxiety of the performers being the noisy intervention in the performance process. I was unable to recognise this at the time. I perceived the 'failure' of the event as inhibiting my performance, yet the audience experienced this as a successful concert and it was well received. The absence of sound from the machine compelled the performers to engage with the discomfort of a silent creative boundary line. The boundary line proved fruitful, as predicted, even though the individual performers' established aesthetics (including my own) made it hard to observe in the moment.

These questions continue to drive revisions to the system and its conceptual design and allow interrogation of my own prejudices towards noise events, be they sonic or procedural interruptions. With practice I may be able to observe these noise events and use them with greater speed and resonance.

A re-imagining of the loop recording layout was made in light of what I had learned from its earlier technical failures and the outcomes of the two concerts just discussed. These failures referred to the operational interference that rendered the systems unusable as well as the days that would be required for a single fragment to loop before any drift would be noticeable between the elements. The new design did not use unexpected machine intervention (such as the afore-mentioned chip drift unit in the guitar and the DAW-generated random variables), however, it did create an element of unpredictability and noise of an interventionist nature. At the time I felt that this was possibly a result that was 'second best', something settled for in light of the 'failures' of the machine-led contingency designs up to that point. However, it has developed into the most musically and creatively fruitful configuration thus far given the wide variety of sonic outputs that become possible. This design was used in the recital, based on the *Hymnus Caesus Obcessiones* composition that took place in February 2014 (and is presented on the accompanying DVD, *The Cyber-Guitar Recital*).

For the T.E.P.P. concert performance of *Hymnus* three loop units were not linked and were positioned so as to record at the three different signal path positions in the effects layout on the floor. The cyber-guitar has three signal outputs which are directed through a series of floor-based units consisting of parameter variables that are continually affected by the mechanical exoskeleton worn by the user.

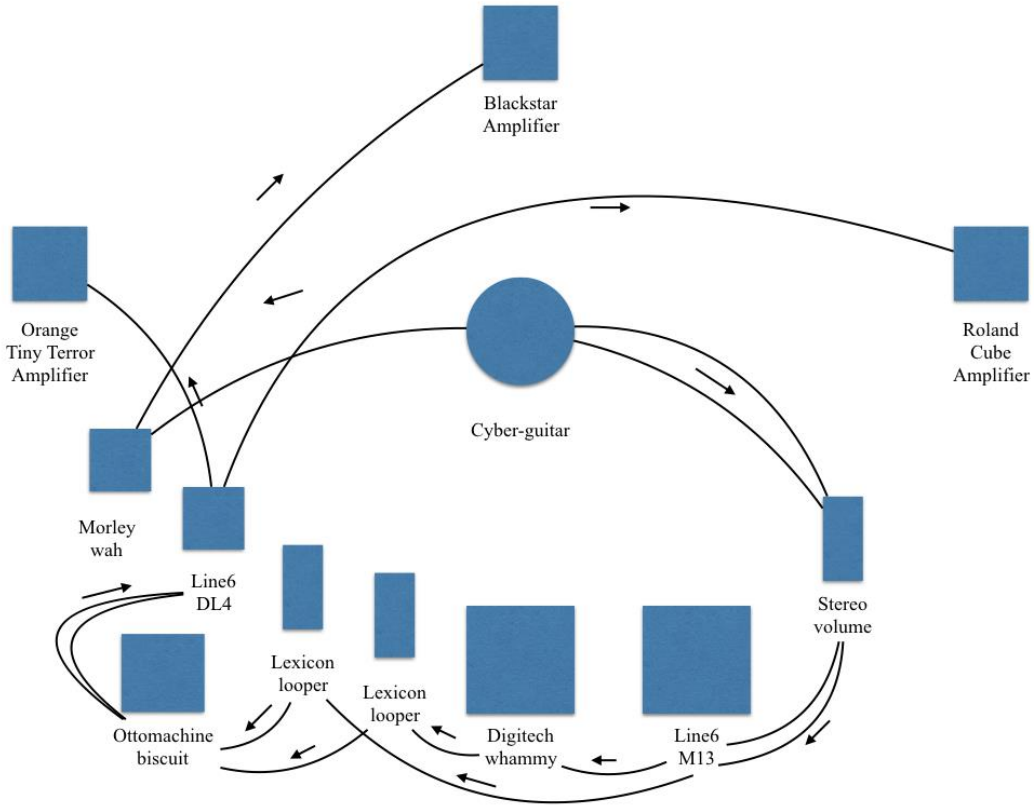

Figure 15: Floor board effects signal path for the *Hymnus* recital.

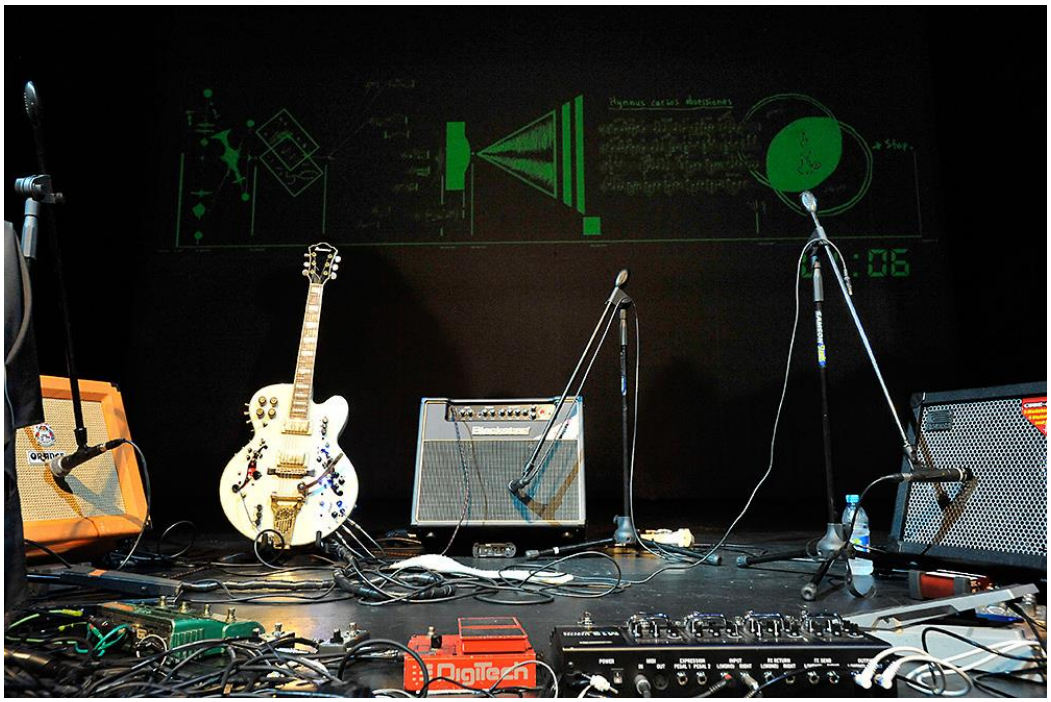

Figure 16: The floor board effects layout for the *Hymnus* recital. Photograph by Christo Doherty.

The worn exoskeleton part of the guitar (the design and construction of which is discussed in detail in chapter 4) offers control capacities for the floor-based effects processors. Due to aspects of its design these variables are part intentional, part random and the new position of the loop units allowed for capturing these changes pre- and post-recording.[26] The separate signal paths were then recorded. Some emerged from the three direct internal guitar signal paths while others were recorded after modification by additional floor-based effects units. This recorded material from the guitar was then re-recorded in three separate sections, in turn affected by the variables from the exoskeleton. After these modifications, two of the variables were recorded into an additional stereo loop unit and further affected by the exoskeleton (listen, for example, to 4:00-5:00, chap. 5 of the DVD). The layering created by these multiple loop fragments and their similarly repeated modified parts created interrelationships within the loops due to shared sonic material.

The layered material and its evolving nature can be considered historically in light of phase composition although the sonic results more closely resemble the work of Tim Hecker, as heard on his albums *Dropped Pianos* and *Ravedeath 1972* (both from 2011). In Hecker's work the musical experience is one that slowly unfolds with layer upon layer of material creating waves of sonic density. Similar results to these occurred in the *Hymnus* performance (listen to chap. 5 of the DVD). The unpredictability of the end result fulfilled the desire for a contingent expression within the loop system. The contingent within the T.E.P.P. loop system is different conceptually to that of the two previous systems I used in concerts and as described earlier. It does not contain a software-based randomised variable component. For it was precisely the software randomised variable feature that I found (at that juncture of the project) to be somewhat contrived and, therefore, possibly not as noisy as one might desire. For the T.E.P.P. concert I chose not to include a synthetic intervention in the entire signal path design, removing the potential for a level of rehearsed predictability. I felt that such predictability would remove the possibility of contingent audio results.

[26] These design aspects and the rationales behind them are covered extensively in chapter four.

At this juncture in the project's life, that is after the *Hymnus* concert, I was concerned with the following problem: if the technologically deployed contingencies that are an inherent (and continually changing) part of the system were to cease having unpredictable results (as an integral part of their actual deployment) they may yield themselves to sublimation under the conceptual arc of musical language, as I outlined earlier. By its very design the contingency aspires to be a type of noise in that it offers interruption or intervention within the musical process. It ceases to afford this if it becomes repeatable and an integrated part of the musician's process, whether improvisational or compositional. In response to this possibility, or even eventuality, I have actively continued to explore, and even expand, the level of contingent change or random variability within the configuration. The specific type of variability or randomness that I have sought, however, is not one that I found could be achieved through random variable generators, as this seemed to create an aesthetic duality. There is a fine line between the contingent and the chaotic.

For example, an approach was taken for the first time during the *Hymnus* concert to employ auxiliary routing interventions manipulated by the sound engineer. The interventions were 'level' and 'mute' adjustments that were applied by the engineer to the various monitor send values directed to the two drummers and the bassist. These interventions were suggested for certain segments of the score and represented an intervention in the expected flow of information to the performers; however, their actual deployment was left to the discretion (the 'improvisation') of the engineer. Here an unexpected signal change to the improvising performers was an example of noise as a process that compelled the performers to make unexpected adjustments. Although the process was noted in the pre-concert discussions these interventions were not rehearsed and were made by the engineer in the moment. The process involved this on-going exploration and active resistance to the pressure one might feel to standardise the performance (especially, perhaps, for examination purposes).

More recent performances in 2015 (after the *Hymnus* concert in February 2014) have been presented with only two performers and these have yielded very different musical results. While the cyber-guitar's system configuration as used in the *Hymnus* concert has remained partially fixed for its longest duration yet, the variation in musical output has been influenced

only by changing the number of musicians involved in the performance.[27] This I find encouraging as it points to a level of flexibility, or a fertile musical instability. The noisiness in the system expressed through its ability to sound the unexpected is reflected by the improvisational reactions of regular collaborators to it. Thus drummer Jonno Sweetman sounds radically different from performance to performance as the system, user, and collaborators are propelled into a continually modified creative space, one which is always shifting through technological flux.

Considering sublimation in convention

As discussed earlier, the subsuming of noise into musical language has characterised musical development in the twentieth and twenty-first centuries. Various types of dissonance, for example, were considered to be 'noisy' at moments throughout the history of Western music. These have, however, been subsumed over time into existing musical languages and have become musically accessible to the broadest selection of practitioners through repetition. In the technological sense, the machine or technological variation created through unpredictable failure or contingency represents the ongoing growth of the language or body of knowledge. Music draws vitality from the non-musical, the noise.

Sean Higgins explains that, "In musical listening, the senses are given a sonic event and within the predetermined model the subject recognises it as a general sonic object, such as a major triad, by aligning that given with what it remembers, conceives of, imagines…to be musical. The sonic object's identity is secured in advance by the musical model" (In Hulse and Nesbit 2010:560). The listener defines the sonic as music or not based on pre-existing memory of materials, allowing categorisations of noise or music to exist for them. This model

[27] The duet format used for the performances during 2015 allowed for the performers' presence and improvisational agency to be more evident. The concerts in 2015 were duets with a drummer and, as there were only percussive acoustic events from the drum kit and all other sounds came from the cyber-guitar system, the sonic distinction was easier for the performers to navigate. This limited the technological contingencies located within the cyber-guitar system and, thus, the agencies of the individual performers were more distinct and recognisable.

does not allow for expansion of the musical event. Rather the growth of the musical event is not contained outside the boundaries of this musical model, by the challenges that noise brings, the sound of the erroneous births the new creation yet the vitality of these fades through eventual sublimation.

The idea of sublimation offers a lens through which one can view the growth and decline of conventional Western harmonic practice, as it pursued ever higher realisations of harmonic system complexity. Similarly, the acceptance of the 'flawed' system of equal temperament, extended chromaticism, and integral serialism, can all be considered examples of dissonance that gradually became accepted as consonance.

Reflection upon these systems as involving a drive towards a fixed endpoint is useful for my own thinking, even though my own work is not grounded in traditional practices of harmony. For instance the acceptance of equal temperament, which is argued to have been invented by the French monk and mathematician Marin Mersenne circa 1750 (Henderson 2014), represents a gradual sublimation of contingent elements. The new 'out of tune' equal temperament system would have been experienced as different, jarring or noisy at the time of its innovation, but the acceptance thereof over time has removed the 'noisiness' from our perception of it. Due to repeated exposure our ears no longer hear the inherent beating caused by the clashing of waveforms in equal temperament (as opposed to the absence thereof in just intonation).

By accepting the 'unobserved' nature of noise we can widen our consideration of its pervasive influence on music. Annoyance is a commonly observable outcome of noises that are deemed to be unpleasant (Vastfjall, 2002:357) or noises that are brought to the fore due to their contextual location (such as a cough in a concert hall). (There are admittedly other noises that do not come to attention through annoyance, for instance the hum of a fridge or computer fan. They are not annoying due to sensory adaptation.) If we accept that "noise annoys – at once simple-to-grasp kernel and yet capable of inflation into the most grandiose theories of subversion" we need to then ask "who is there to be annoyed, and in what ways?

What is noise anyway?" (Reynolds in Cox & Warner, 2010:55). In being annoying a noise brings itself to our attention, and, one may ask, is this not a musical action in itself? Is the annoyance of a cough in a concert hall or a crying baby in a church sermon not a sonic evident demanding of our attention? Could we not think of music as structurally curated noises that entice people to pay attention through varying levels of pleasure and annoyance? Does the musician not balance this out in their practice by drawing attention to their curated sounds through subtle manipulations of context, social acceptance and challenges to convention?

Thus far this chapter has considered concepts and application of noise with reference to technology, composition and improvisation. The following section is an overview of the historical consideration of noise within music. The question of how precisely to define noise (in music) was first tackled by the Italian futurists (Russolo, 1914). Specifically, their query regarded the relationship between music and the specific society in which it exists. My own project uses this inquiry as a springboard.

Introducing noise into the confines of existing compositional form

In 1914 Luigi Russolo published his manifesto *The Art of Noises* in which he proclaimed that the future of music was in noises – the noises all around us, the auditory signals of technological advancement – or in the potential emancipation of man through technological advances. He envisaged music as artificially constructed from the sounds of the machinery and urban life of the time, sounds that became all too evident in his surrounds:

> In antiquity, life was nothing but silence. Noise was not really born before the 19th century with the advent of machinery. Today noise reigns supreme over human sensibility. For several centuries life went on silently or mutedly. The loudest noises were neither intense nor long nor varied. In fact nature is normally silent except for storms, hurricanes, avalanches, cascades and some exceptional telluric movements (Russolo, 1914:4).

Russolo's very specific categorisation of noise as a new entity, born of the development of machinery, clearly excludes natural noises, or the noise expressed in the tensions of new musical developments such as I described in relation to tuning and harmonic systems. He created musical instruments to make these noises, and his *Intonari* (or noise-making machines) were designed to create sounds specific to his time. Russolo's Futurist aesthetic is firmly located within a narrative that looks into an imagined machine-driven future as a positive set of possibilities initiated, facilitated and mediated through accelerated technology.[28] Russolo's views on technology were elative. They were not in line with the prevailing negativity regarding industrialisation and its machines (Lee 2003:121). By contrast, Russolo heard advancement, emancipation and development in noise. For him noise was a contingent force presenting itself for the benefit of society and music. As Salome Voegelin has written, Russolo celebrated noise:

> He heard in the machine the sounds of progress, liberation and advancement of a people towards a better life that had overcome the imperfection of the menial and manual in the perfection of the machine. His work accompanied and sounded the Zeitgeist of objective reality, of a faith or doctrine rather that the humanity in mankind should be overcome in the perfection of its creation (2011:43).

Russolo's aesthetic ideals outlined in his manifesto were admirable and imaginative, but not necessarily realistic. They also stand in stark contrast to the pragmatic methods he proposed for their auditory realisation and inclusion in performance. He asserted that the environment of contemporary composition, as he observed it at the time, was striving for increasingly angular, mathematical and dissonant selections of standard musical materials. He imagined that the inevitable outcome of the creative pursuit of this complexity would appear as noise. In his view a new music should be derived not from the constraints, rigours and mathematical extensions of the harmonic, melodic or instrumental systems of the time, but rather would find inspiration for new source material from machinery and industrial society. We can now

[28] Russolo's perspective on the imagined future for noise musically is not as important for my work as the conceptual boundary it offers for the germination of his ideas.

recognise the naivety in this view. Also, his assertions were often fraught with contradiction. For example, in defending noise he enlisted the sounds of nature – "thunder, wind, cascades, rivers, streams, leaves" (Russolo, 2004:7) – as noisy artefacts themselves, whereas elsewhere in the manifesto he seems to refute this. As discussed earlier, the reduction of noise to 'non-musical' elements (as sonic elements standing apart from the accepted usable elements of music at a fixed historic point) results in complications due to the artificial nature of this divide. Russolo's seemingly contradictory inclusion of natural sounds also highlights the artificial nature of the division. Instead, noise could be sonically defined as the 'yet uncategorised'. Noise in this case would refer to the sounds that have not yet been officially labelled, stamped, and sealed into the canon of musical usability.

It is in Russolo's recommendations for the application of the various noises and sounds mentioned within his proposed musical systematic categorisation that one finds a telling tendency:

> We want to score and regulate harmonically and rhythmically these most varied noises. Not that we want to destroy the irregular movements and vibrations (of tempo and intensity) of these noises! We wish to fix the degree or pitch of the predominant vibration, as noise differs from other sound in its irregular and confused vibrations (in terms of tempo and intensity) (Russolo, 2004:9).

In other words, he advocated a classification of noises into categories that would facilitate their sublimation in the light of traditional rigours and forms, of structure and arrangement, treating them as new material for existing musical technique and form. At the same time that the manifesto proclaimed the emancipation and exaltation of forms of mechanical noise it advocated an adherence to musical practices within the existing structures of music. In those assertions, that were revolutionary and laid the groundwork for much to come, we can recognise that the tendency to subsume the foreign, unusual or 'noisy' into the practice of noise-based music seemed, for Russolo, to be unavoidable. He saw no observable conflict between this and the assertions towards emancipating noises. In his manifesto he proclaimed the emancipation of noise, but felt compelled to categorise and use noise in standard practice.

By doing so he not only rendered noise as music, he also undermined the contingent elements that would reveal themselves through its inclusion.

Considering the use of noise in opening up compositional process

In 1937 Cage penned *The Future of Music: Credo,* a manifesto in which he related his outlook for future developments in music to aspects of Russolo's early work. The two seem to share many principles. Cage reiterates the growing inclusion (or sublimation) of noise into the realm of musical expression, although the list of possible sounds in his framework includes industrial as well as natural noises. In *Credo* Cage argues for including a greater variety of noises into composition and that the enlarged landscape of music would be enabled through technological advances and undiscovered musical and, specifically, technological methods of creation. Unlike Russolo's *Intonari* that were loud, crude expressions of their time, Cage advocated for the technological creation of new, specifically definable sounds. He asserted that these should be scientifically precise, and be able to be manipulated with extreme accuracy as per the desires of the composer. The *Intonari* mimicked a small, selected set of sound types that were imitations of an extremely narrow but aesthetically important selection of industrial and machine noises (no doubt some of the most prominent at the time). Whilst Russolo advocated the inclusion or imitation of pre-existing and contemporary noises as a sonic reflection of modern society, Cage's narrative in *Credo* seems rather to predict the separate fields of *musique concrète* and *elektronishe Muzik* before they were fully formed. For example, in advocating for the rise of noise within music Cage foresaw the development of accurate machines able to precisely manipulate "frequency, amplitude and duration" (Cage in Cox & Warner, 2010:26). This predicts the specifics of synthesis and the aesthetics of musical control common to *elektronishe Muzik* whilst also leaving room for the captured sound world of *musique concrète*.

Cage further asserts in *Credo* that, going forward, the composer will now "be faced not only with the entire field of sound but also with the entire field of time" (in Cox & Warner, 2010:27). The understanding of sound here, that includes noise, is presented as opposed to

the world of music (or organised sound) and, I argue, points towards thinking of the difference between music and noise as similar to the difference between consonance and dissonance. Cage contends that compositions derived from the processes of harmony, or even the harmonic processes themselves, subjugate all elements included in the musical work to the techniques of harmonic practice and their deployment. He felt this strongly even whilst a student of Schoenberg and recalls,

> Schoenberg asked me whether I would devote my life to music, I said, 'Of course.' After I had been studying with him for two years, Schoenberg said, 'In order to write music, you must have a feeling for harmony.' I explained to him that I had no feeling for harmony. He said that I would always encounter an obstacle, that it would be as though I came to a wall through which I could not pass. I said, 'In that case I will devote my life to beating my head against that wall' (Cage, 1959:260).

A harmonically-derived system of composition is hierarchical, being a system of power relations. Adherents of the twelve-tone system perceived its advantage to be the attainment of the goal of equality conferred on the individual pitch elements, even if this equality was artificial. The nature of aleatoricism may seem to be the complete opposite of this goal, in essence a differing type of equality conferred onto musical materials through abdicating the structural constraints to chance. By attempting to confer equality onto the greater breadth of musical elements through chance the composer and compositions in fact only reinforced the presence of what was a different yet equally artificial hierarchical system. This type of synthetic systematic approach to material, whilst seemingly aesthetically different is a mirror in its nature.[29]

There are a number of implications to these developments. Firstly, the intention of giving equality to all tempered pitches through the rigour of serialism is a questionable aesthetic project due to the synthetic nature of its goal. Collins refers specifically to the treatment of

[29] While by the rigor of integral serialism all elements of compositional practice were subjected to the serial technique, all elements were hierarchically equal in weighting even though the weighting was artificial in its application (Kostka 2016: 274).

pitch in this process, saying that it was "systemised to death by the Second Viennese School and its followers" (2011:3). The inclusion of equal temperament's existing artificial subdivision in itself excludes the greater breadth of frequencies, both in terms of potential pitches and, also, by narrowing the view to tempered materials the exclusion of noise is unavoidable. Secondly, this development excludes all noise due to its non-pitchable nature, thereby, providing a rationale for the different projects that argued for noise's inclusion, such as those of Russolo and Cage. It also, however, highlights fault lines in Russolo's and Cage's thought and work, and reveals their anxiety with regard to the 'place' of noise in their practice. Russolo, we have seen, desired to give his system legitimacy by bringing noise into contemporary compositional practice as a supporting system, validating his work, including the *Intonari,* by presenting them in the 'tempered' framework of music and techniques of the time. Cage expressed this discomfort by presuming the need for 'new' sonic creation, rather than interrogating the segregation of the old and the noisy through the structural rigours of existing compositional practices. In Cage's creative world, by making all things new the problem of sublimation is thus avoided.

The *Credo* and *Futurist* manifestos both accepted that compositional form should and would remain as an active line of differentiation between music and non-musical practices. It was viewed as a fixed, conceptual, yet pragmatically fluid boundary between music and chaotic noise, regardless of the concessions given to compositional practices or chaos. In Cage's words,

> The principle of form will be our only constant connection with the past. Although the great form of the future will not be as it was in the past, at one time the fugue and at another the sonata, it will be related to these as they are to each other (in Cox & Warner, 2010:27).

Both the Futurist manifestos and *Credo* valued the inclusion of noise as aesthetic and compositional practice and looked to the future for new sonic materials, instruments and techniques, while both conceded to the retention of certain elements of the past. These

retained elements leave one suspicious of contradictions in their arguments. The goal here, however, is to concentrate on the point of origination of the differentiation: where does the line between noise and music lie?

The ephemeral noise boundary

In the liner notes to the CD *A Call for Silence* Collins (2004) says that "noise has tiptoed across the border into signal", and it continues to tip-toe, unnoticed by the greater majority. I imagine being a part of that journey, to 'tip-toe' along with it, and remain an intrigued passenger. I am intrigued by the process: where does the boundary lie? To more accurately account for the place of noise in my cyber-guitar system project I propose the term 'ephemeral noise boundary'. This notion functions as a central convergence for design, improvisation and composition within my research. Technologically it can be understood as an expression of the point at which the machine interacts with, or at instances can exceed, the human creator in creative propulsion. Intellectually the point of convergence presents an end point and, simultaneously, a new beginning point. It is a point where one aesthetic goal has been realised and, in an instant, a new one begins. The ephemeral boundary itself reveals a fertile point of engagement, an area of continual expansion and creativity. It is a boundary that, in an audible instant, sits neither on the definable side of noise or music and the structures and definitions potentially applied to each. During each musical endeavour time spent creatively interrogating the boundary has yielded the most interesting and encouraging outputs.

To be a performer within this system one has to be at once engaged with the performance and in the same instant open to the unexpected, ready for the newness of possibilities birthed at boundary. The nature of much musical performance (even in improvised arts such as jazz or aleatoricism) is that the challenges of the complexities to be rendered leave little room for contingent events and their use. Through the expression of modernism in music one can observe that the continual extension of logical or numerically-based formulae (and in a sense form expressed at a structural level) push composition and improvisation into continually

increasing forms of numerically derived complexity (Tymoczko 2010: 387). This can be said of both integral serialism within Western art music and the late expressions of hard bop and beyond in jazz and fusion. To observe, explore or fix one's sight on the unexpected, whatever the boundary may afford, however, does not presuppose a rejection of modernity (or harmonic complexity), as described above, or its music-compositional practices.[30] Rather it finds creative value or a nurturing point by focussing on a fleeting or under-explored structural boundary (as imagined through performance). Voegelin's (2003:43) observations of the distinctions between modernism and post-modernism detail this principle. She argues that the post-modern position does not take a negative or positive position on modernity; rather it accepts a specific point within its realisation and then advocates further exploration within this selected area. In this scenario, one might argue that the expression of noise as ephemeral may be different from its use both in the modernist music project and in post-modernist ventures (thus far). One may suggest that the noise-boundary, as a point of further exploration, represents a new point of fertility within creative practice, somehow different from past endeavours.

As noted, Cage's and Russolo's reflections on noise were sonic in nature and their proposals for the inclusion of noise were facilitated through means that would bring noise as sonic material into existing practices. Even the seminal *4'33"* (1952) by Cage can be considered in this light, as noise was brought into awareness via the container provided through the aesthetics of existing performance practice and spaces. The boundary line between them, while fluid and ephemeral seems to have attracted less attention and exploration with music. It tends to vacillate or find it pinned between the poles of mathematical abstraction (both in integral serialism and *elektronische Musik*) and works springing from the aesthetics of *musique concrète*. For instance, Ryoji Ikeda's (2005) data.matrix structures could represent a contemporary music approach to a mathematical modernist-derived structural or form-based compositional agenda whilst still being distinctly postmodern in the aesthetic realisation. Their process-based structural natures are mathematical and, thus, in my opinion, align with

[30] In chapter one I noted the failure in rejecting genres as understood through my own history. By rejecting a genre due to the structural rigours of another genre I assert that one only inhibits creativity. A failure here would be to advocate that the boundary requires rejection of other structural implications. It does not. By its nature it yields the unexpected and creative seeds that can go in any direction.

synthetic structural practices in lineage. Their aleatoric and mathematical processes, however, make them a postmodern project in themselves. By contrast, the extremes of Japanese noise artist Merzbow's works represent a different container, one where form and structure are not present (in a manner recognisable as musical form) and the audio structures never approach mathematical formulisation. Merzbow's technique of continually exceeding the capacities of the technological systems employed is an example that intentionally deploys a compositional approach to create varying or unplanned results. The overloading of the technologies used creates sonic outputs that are not directly the realisation of the performer, but rather by-products of the performer overloading the systems. Here Merzbow is, in a sense, exploring an ephemeral boundary artificially rendered through the overloading of the machine (instrument) of his choosing. A comparison here can be drawn to the destructive modification of the machine, a CD player in this case, by Nicolas Collins. Collins and the German group Oval have both used the techniques of damaging CDs and CD players to create a type of glitching, what Collins refers to as "the benevolent catastrophe" (cited in Kelly 2009:212). Although Collins is associated with the avant-garde, Oval with glitch music, and Merzbow with Japanese noise all three use violence against the machine and medium to create a mathematically unpredictable intervention.

Comparing Ikeda and Merzbow is useful in supporting this argument. That the mathematical formulation present in Ikeda's work, and the way in which it lends of structure to the compositional outcomes differs methodologically from the free events in Merzbow's work, freely unfolding through the overloading of technologies and the contingent outcomes. These subtle differences in generation are to me pointed aesthetic differences regardless of the sonic presumptions of the listener. A listener may experience sonic similarities between the two: both use structure and form as the main container, unfolding in scale and intensity across time, and the materials used are generally perceived as white or pink noise. The delicate sonic nature of Ikeda's work compared to the sensorial violent consumptive quality of Merzbow's would, however, be highly noticeable points of departure. The compositional processes are also vastly different. One is carefully and mathematically planned and the other relies on the failure of systems for the audio realisation. We see that whilst the audio output may be sonically recognisable as noise in Ikeda's work it is only in the work of Merzbow that noise is engaged with completely as a creative tool in performance.

The concept of noise as the modifier of practice is not new, though. Edgar Varèse explained,

> The electronic medium is also adding an unbelievable variety of new timbres to our musical store, but most important of all, it has freed music from the tempered system, which has prevented music from keeping pace with the other arts and with science. Composers are now able, as never before, to satisfy the dictates of that inner ear of the imagination. They are also lucky so far in not being hampered by aesthetic codification – at least not yet! But I am afraid it will not be long before some musical mortician begins embalming electronic music in rules (in Cox & Warner, 2010:20).

Varèse's proposals for the roles of noise, technology and traditional music parameters in music of the future set him apart from his contemporaries. I would argue that his theories and works have proven prophetic. As Cage said of Varèse, "more clearly and actively than anyone else of his generation, he established the present nature of music" (1961:84) . Varèse's focus was not on the functionality or structural complexity of music, but rather on issues of timbre, texture and space. These foci set him apart from his contemporaries in many ways. In the quote above he explains the continual addition of new sounds – noise – as being instrumental in freeing music from the structural (and in my argument synthetic) constraints inherent in the system of temperament and its results. In his essay, "New instruments and new music", which pre-dates Cage's *Credo* by a year, Varèse outlines some of these ideas:

> When new instruments will allow me to write music as I conceive it, the movement of sound-masses, of shifting planes will be clearly perceived in my work, taking the place of the linear counterpoint. When these sound-masses collide, the phenomena of penetration or repulsion will seem to occur. Certain transmutations taking place on certain planes will seem to be projected onto other planes, moving at different speeds and at different angles. There will no longer be the old conception of melody or interplay of melodies. The entire work will be a melodic totality. The entire work will flow as a river flows.

> We have actually three dimensions in music: horizontal, vertical and dynamic swelling or decreasing. I shall add a fourth, sound projection – that feeling that sound is leaving us with no hope of being reflected back, a feeling akin to that aroused by beams of light sent forth by a powerful searchlight – for the ear as for the eye, that sense of projection, of a journey into space (1941 cited in Cox & Warner, 2010:18).

Varèse's view is useful for thinking about the ephemeral noise boundary with which my project has been (pre)occupied. He believed that the continual endeavour to uncover and explore newness in sound and noise may be the means to unshackle the constraints of the temperament-derived systems and free music from its need to polarise itself with noise. Such creative approaches find expression in contingency and boundary observation, and their inclusion into practice. Whilst Varèse was frustrated by the lack of musical machines to fully realise his ideas creatively in the first half of the twentieth century, the contemporary musician has access to technologies that can more easily realise these goals. The technological means to inhabit the contingent is now more easily within reach. The cyber-guitar system has interrogation built into it and expresses it in the variety of electronic systems and physical construction processes (which I discuss in the 4th chapter), and creative approaches to notation and performance practices used thus far (which I discussed in the previous chapter). I will continue to explore these both in conception and also attempt to leave controllable room for unexpected contingency.

I consider the ephemeral noise-music boundary as a point of creativity and a point of error exploration that, once observed, can be applied in order to continually broaden the field of practice. Indeed the error or contingent represents the area of 'failure' within the interaction between a machine (be it a technological machine or a traditional musical instrument) and a human, but it is an area fertile with creativity. In my own practice this was something difficult to accept as every part of my lifelong training worked towards elimination of error and perfection in replication. On the accompanying DVD performance of *Hymnus* two specific examples are worth mentioning. In section four of *Hymnus* there were two stopping points agreed upon in the score, at which the entire group was to pause and then restart. At

the first of these (at 3:53–4:04, chap. 4) the group stopped cleanly but I triggered a loop mistakenly prior to the re-entry. At the second point I elected to do this again (at 4:34–4:45) reacting to the shape of the previous event. Another example was at a performance of the cyber-guitar at the Unyazi Festival of Electronic Music (Johannesburg, 2014) where a number of the switches began clicking for an unknown reason. I looped these unexpected 'error' events and the drummer Jonno Sweetman began improvising to the looped click fragments.

The ephemeral boundary allows for the growth and increase of knowledge within the field via continual exploration and observation followed by categorisation and eventual sublimation into the language. If the contingency itself (or ephemeral event) is genuinely a productive area of interrogation (sitting firmly on the boundary between technological operation and failure, noise and music) is it not reasonable to assert that this noise and music boundary represents the most explosive creative possibilities? For this reason this project has not sought to explore what one might consider the extremes of either noise or traditional music-compositional techniques and rather seeks to situate itself in the process of exploration of the ephemeral boundary.

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At the outset of this project I was unsure of the function of noise within the project, but recognised its influence. This chapter has served to locate the specific types and conceptualisations of noise I used in this project – noise that is both sonic in nature and noise as a driver of the creative endeavour.

The cyber-guitar system contains elements of both categorical, traditional musical practice and noise elements. The first is represented in aspects of the composition, improvisation and form (as illustrated in the seventh section, the hymn, of the T.E.P.P. composition *Hymnus*). The second was realised in, for example, the presence of bit crushing, delay feedback and white noise linked to the complex variable actions of the exoskeleton system. However, beyond the use of these two facets, the most significant feature of the project, I would argue, is in the exploration of the imagined boundary. In other words, determining and describing

the noise outputs is not as important as the continued searching for undiscovered material. I argue that the processes of performing with the system and the ongoing modification thereof yields continued growth and expansion of knowledge in the field and whilst perfection (in any sort of modernist sense) may never be attained (due to the continual incorporation of the information observed), the process is perhaps the more important endeavour. The system's capacity to allow itself to integrate sounds, structures, and styles from a wide range of genres emerging from multiple aesthetic positions suggests that its 'playability' is an inherent feature, one that is arrived at and maintained through its expanding nature.

How the outputs of the notational and noise impulses that I've discussed thus far resulted in the changes to the instrument and design is what I turn my attention to next.

Chapter 3

Designing the cyber-guitar: Understanding instrumental design and organology in context

Introduction

Organology is the study of musical instruments, their science and their classification. It has traditionally covered their history and cultural usage, their mechanisms of sound production and the classification thereof. For the purposes of this study I wish to consider John Tresch and Emily Dolan's re-definition of the field in the paper "Towards a New Organology". They propose re-thinking organology as what they term "the ethics of instruments", which is constituted of four categories:

> 1. The material disposition of the instrument: the nature and configuration of its elements, and the materials and parts that make it up. Also, and perhaps most important, this disposition is defined by which parts are seen as necessary to make the object an instrument of a certain type, and which may be varied to alter its specific action.
>
> 2. The instrument's mode of mediation: whether its action is considered to be autonomous or passive, modifying or transparent, hidden or visible.
>
> 3. The map of mediations of which the instrument is a part. Such maps, joining together a number of distinct elements, may be rather complex: in music they include air, sound, composers, players, other instruments, and listeners, as well as orchestration treatises and rules of composition; in the sciences they include the phenomena being investigated, the observer or experimenter, and other elements in the experimental system, as well as rules of method, laboratory protocols, scientific institutions, and patterns of moving between observation and generalization.

> 4. The telos of an instrument's activity, or its ends. What is the nature of the enterprise within which the instrument is deployed; what are its social contexts and uses, and the social, economic, and political relations they express, reinforce, or perhaps modify? At the level of telos we might also want to bring in broader conceptions of the goals attributed to instruments: not the instrument's relation to itself but its relation to its users and those exposed to its products, as well as its impact on the entire collective. Furthermore, we might consider the relationship an instrument is seen to entertain with the natural order, with the cosmos as a whole (Tresch & Dolan, 2013:284).

My use of the term organology is linked to these conceptions, and for the purposes of the cyber-guitar the above four categories have all equally informed what I understand to be the organology of the instrument. They have impacted and shaped the design, but the over-arching design has not been limited to its technological development. The developments are equally or symbiotically dependant on areas which would normally be excluded from organological study such as the considerations of noise and notation in the previous chapters. Tresch and Dolan see agency within the instrument-object itself, a flowing of influence between user and instrument, prosthetic and human. The ethics of instruments or 'new' organology explores "the different forms and degrees of agency attributed to instruments." This "suggests that the qualities of sentience, activity, and intention might not always belong only to humans but also to objects often classed as inanimate, including machines and instruments" (Tresch & Dolan 2013:284). This proposes a type of symbiosis between musicians and instruments that is also a cybernetic relationship.

Weiner's (1961) theories of cybernetics provide definitions and explanations of the interfacing between machines and humans. Musical instruments and their history of technological interfacing, however, predate this. Upon consideration the musical instrument reveals itself as one of the earliest examples of a technological prosthesis. It is a prosthesis that has a reciprocal relationship with the user. The relationship between musician (as user) and instrument (as technology) requires exploration: it provided a foundation upon which I could critically reflect on the design choices and other creative decisions that I took in the development of the cyber-guitar system, as well as how these choices influenced the project.

Although the modern guitar's history is relatively recent compared to many instruments, and has involved many organological changes in its visual presentation, it embodies a variety of cultural meanings that are recognisable in its various expressions to this day (Turnbull, 1991:60). From the romanticised classical guitar as popularised during the early twentieth century by Andres Segovia to the electric guitar as a symbol of male power in the music of Jimmy Hendrix and Led Zeppelin, the guitar affords many cultural meanings through visual associations that receivers have with its various organological forms (Ganetz 2011: 406).

A musical instrument has a symbiotic relationship with the development of the technical skills required to compose for it and to perform on it. This is a developmental process, one in which the composers and performers imagine new sounds that often propel revision of, and innovation in, instrumental design (Godlovitch 2002:61). Such design changes may involve large structural changes at certain points in an instrument's history, as in the changes to the lute and vihuela and their evolution into the acoustic guitar (Koonce 2010:1). However, many other developments are small and less noticeable, such as the changes in materials used for the manufacture of strings. New instrumental developments lead to new performance requirements that, in turn, influence the demands on techniques that are then passed on through subsequent training and practice. These are then subsumed into instrumental performance practice and become part of the compositional narrative associated with the instrument (Crispin and Gilmore 2014:145). These techniques often require small, nuanced movements that are not necessarily observable to the eye of the audience member and take years of refinement and development on the part of the user, forming part of their unique skill base. In my own observation it is often a point of pride or musical authority in listening culture when these nuances and fine motor movements or gestures are observable to listeners, and their musical results heard.

In most cases additions to an instrument's signal generation have been confined to the physical boundaries of the instrument itself. This is due to the resonant nature of a closed system of sound creation in which the string, reed or any other activating device is in direct

contact with the resonating body of the instrument.[31] With the development of the electric guitar in the twentieth century, however, guitar design conceptualisation moved away from a focus on the acoustic nature of the instrument. Initially the guitar's electrification was principally propelled by the need to raise the volume of the instrument within a big band setting (Gibson 2011, section 5). The guitar had been a second choice to the banjo as the banjo's volume and sound (being accentuated in the middle range of frequencies) was able to carry over the band's volume. The first documented electric guitar was the Rickenbacker 'frying pan', an instrument that looked much like the name, first patented in 1934 (Lähdeoja, 2008:1). The electrified guitar and amplifier modified the function of the guitar within the big band format: now the guitar could, with adjustable volume, take solo passages and not only perform as accompaniment. The guitar's volume, no longer limited by its acoustic level, could be defined at will by the user.

The nature of the amplifier and the later creation of guitar effects pedals spawned an entirely new ecology in organology (Waksman 2001: 12). Signal modification initially only related to amplitude, but further modification then took place outside the instrument on the signal's journey to the amplifier with an increasing number of parameters that could produce a variety of effects. These signal modifiers were, notably, physically out of contact with the practitioner's body. The guitar's timbral nature, and the psychoacoustic properties thereof, is retained as part of the created signal by virtue of the components of the instrument that have remained constant and due to the manner in which the player activates the strings while the amplitude of the volume is variable.

This new ecology was quickly adopted by popular and experimental musicians and, since then, musicians have expressed a growing desire for ever more varied signal changes, leading to a dizzying variety of processors and, on each of these, an ever increasing variety of complementary control possibilities. The variety of processors available is not only a result of

[31] A closed system in this regard is one in which the potential to vary a musical instrument's output is confined to the instrument's body. "Since sound waves represent energy, and since we know that in any closed system the total amount of energy must be conserved, when sound waves are generated some source must pour energy into the system that produces them" (Moravosik 2012:130). An electric guitar or any electric instrument has the potential for signal creation and signal variation to be made through other means.

the sonic modifications they afford, but also their flexibility as non-permanent additions to the instrument. Processors in general do not require modification to the body of the instrument and, thus, need not require radical new performance techniques on the part of the user as would have been the case if they were a fixed part of the instrument. The developing organological ecology of the guitar did not, in the majority of cases, invade the instrument itself, as both 'stomp box' effects and rack mounted effects were located outside of the instrument and did not intrude on the fundamental playing techniques of the user.[32] This could be said of the synthesiser too which, with the guitar, is perhaps the other most important electrified instrument. Here, the keyboard and pedal mechanisms remained and the synthesis systems, whilst embedded in the instrument, do not require modification of the core components of the performer's technique.[33]

The motivation for bringing electronic technologies into the body of the guitar in this project was at first a pragmatic one, borne out of the frustration with having to physically bend down to the floor continually to modify effects parameters during performance.[34] I did not set out to explore or understand the boundaries of instrumental design and gestural interfacing, but was rather trying to find a pragmatic solution to what was a performance problem. As the project

[32] There are many commercially available design examples of exceptions to this, though. For example consider the various midi guitars such as the Roland G-707 and the Casio DG-20. Further, there are a wide variety of guitars available with in-built effects. Some examples of this include the Gibson Firebird-X, the Vox Ultrasonic, the Alesis XGuitar and the Bilt Revelator, that has a Theremin-type quality and a variety of effects. Initially the cyber-guitar build planned to have the internal stomp box parameters mapped to the later exoskeleton; however, this was abandoned for pragmatic reasons during the build process.

[33] Again, noting the exceptions to this premise, many keyboard free synthesisers exist from Don Buchla's experiments to Korg and Moog. It is worth noting that Robert Moog's original synthesisers did not include a keyboard and it was only after the encouragement of a business partner that the keyboard was included (Pinch, T and Trocco, F 1998: 17). The ensuing commercial success of Moog over Buchla speaks to the desire of instrumentalists for the inclusion of familiar components of an instrument for ease of inclusion in their performance practice.

[34] The reason for having to bend down and modify parameters by hand was due to the number of parameters and types thereof. Generally the parameter accessible via a foot pedal is an 'on or off' state, and not the other variables which are pre-set. Many guitarists have taken to placing effects pedals on a table during performance to alleviate this problem, as in the work of Eivind Aarset that requires the guitarist to be seated. Some have even gone so far as to place the guitar itself in a 'table top' position or used prepared guitars like Keith Rowe. In the case of the latter conventional guitar technique is abandoned altogether. I sought to use both eventualities: by bringing the effects into the guitar I had the advantages of table top effects whilst being able to remain standing and use my feet for further control.

proceeded, and questions regarding noise and notation were highlighted, the process of trying to find solutions to musical challenges deepened. I found that the tensions between noise and music, the values ascribed to notation (as mentioned earlier), and the tensions surrounding organological innovation have been present in many aspects of my work on the cyber-guitar. My explorations of these issues also preceded this research project and have informed or directed what I first thought were goals related to improving the performance experience on a complexly modified electric guitar.

The design of any musical instrument exists in a relationship to the growing capacities of a practicing musician: the boundaries of its use are always present. These are generally accepted and even unnoticed, although there are occasional interrogations. Any musical instrument is as an object imbued with various meanings, aesthetics, social values and moral imperatives that are both socially imparted and pedagogically passed on. Eliot Bates notes that musical instruments exist

> not simply as things that humans use or make or exchange, or as passive artefacts from which sound emanates. Much of the power, mystique, and allure of musical instruments, I argue, is inextricable from the myriad situations where instruments are entangled in webs of complex relationships—between humans and objects, between humans and humans, and between objects and other objects. Even the same instrument, in different socio-historical contexts, may be implicated in categorically different kinds of relations (2012:364).

The musical instrument, as a technological system, is a prime example of social constructionism at play in technologically dependant artistic practice.

Anthropomorphism and/or introjection through prosthesis

Professional musicians tend to hold reverence for their musical instruments and justly so given the amount of time invested in them and the place an instrument may hold in the

lifelong experiences of the practitioner (Rojas, 2015:208). Many years of specialised practice, devotion and revenue will have been poured into the mastery of a specific instrument in a specific organological state.[35] As a sound engineer I once had a difficult interaction with a well-known pianist who felt the piano would be somehow 'hurt' by having a microphone too close to it. He believed that the instrument was a 'living and breathing thing'. While most would recognise that the object is not in itself alive, attributing anthropomorphic characteristics to instruments is common (Powell 2001: 194). Many musicians have, thus, named their instruments, as did BB King his guitar Lucille. Other musicians find a spiritual value in owning a previous master's instrument. For a number of years I owned a standard model Gibson jazz guitar previously owned by South African great Johnny Fourie. The instrument also had an attachment (albeit loose) to the international guitarist John McLaughlin and for many years I felt a tenuous link to both of these master guitar players. I realised after a time that the connections, however obviously imaginary, permitted a process of what one might call introjection, in which I took imagined properties from the previous owners into myself through the vehicle of their instrument. Although at the time I felt a sense of increased capacity from these introjected elements I now recognise that they impacted my own creative practices negatively. The instrument facilitated this relationship and I then sold the instrument to free myself from the constraints I appropriated.

The various interplays between musicians, their instruments and the relationships they facilitate (be this through introjection, projection or anthropomorphism) may also be understood as aspects related to the adoption of a musical prosthesis. With any prosthesis (be it a limb or an oboe) the 'wearer' gradually integrates the prosthetic into the extended body in such deep ways that its absence is felt in an embodied manner. The experience is one in which the instrument has become part of the body. Luc, Lesaffre, and Leman explain,

[35] In my experience the dedication may not only be to an instrument type, but to a specific variation of the instrument as made by a specific manufacturer. Electric guitarists can be devoted to an instrument model made in a single year and single factory location, for example, a Japanese 1980 Gibson ES-335. Although the instruments are mass produced, the various guitarists accord value to them comparable to that given to instruments made by specific craftsman.

> a symbiosis between musician and musical instrument results from a growing integration of instrumental and interpretative movements into a coherent whole that is compatible with the body of the musician and with the movement repertoire of daily life. Such integration leads to the transparency of the musical instrument that just like "natural" body parts disappears from consciousness. The musical instrument has then become part of the body as stable background of every human experience and is no longer an obstacle to an embodied interaction with the music. It has become a natural extension of the musician, thus allowing a spontaneous corporeal articulation of the music (2009:1).

With the individual becoming intermeshed with the instrument not only in their artistic expression, but even with their sense of self, modification may be akin to an imagined surgical intervention. Thus the instrumental prosthetic enjoys the same level of protection by the user that any other bodily appendage may, expressed both physically and psychologically.

This blurring of the boundary line between the tool and the body of the user is fluid. The tool is increasingly absorbed into the user's reality, becoming an ever more integral component of the extended body. The tool may be obviously inanimate to the external world, but as in the sublimation processes I discussed in terms of the noise boundary, this line is also fluid. Grosz explains that "it is only insofar as the object ceases to remain an object and becomes a medium, a vehicle for impressions and expression, that it can be used as an instrument or tool" (1994:80). I would add that there is no single moment of change when this happens because the item remains in both states at all time for the user and as the item increases in complexity aspects of its use facilitate a fluid motion between each of these various states.

Veronica Doubleday's work on musical instruments and gender shows how musical instruments are important artefacts of culture and are imbued with meanings and powers. To own or to play an instrument "is to wield power" (2008:3). Doubleday explains that an exclusive instrument-human relationship develops, forbidding outsider access, when a certain group of people wish to retain control over a particular musical instrument. A musical instrument can become so heavily invested with power that it assumes an intensity that could

almost be termed a fetish. This would imply that to engage in the adaptation of an instrument could potentially involve the risk of troubling power positions that may jeopardise the standing of the musician in their community or with their audience. It may be that many of these processes are responsible for the rigid stability of design in orchestral instruments and are at play in the reluctance shown by musicians from other genres to engage in organological adaptation as well.

Magnussen (2009) expands the notion of a user's embodied relationship with a musical instrument considering also cognitive relationships. An instrument functions not only as an extension of the body but, he argues, as an extension of the user's mind. What is of importance to consider is that the flow of information entails a two-way process between practitioner and instrument or body and wearer? The performer attempts to master the instrument whilst the organological nature of the instrument (expressed both physically in design and socially through history) imposes (received through willing compliance) both observable and unobservable boundaries onto the types of mastery attainable. For example, while it is now common for jazz pianists to use either their hands or other objects to create alternative sounds from the piano, this was not always the case. Prior to Cage's prepared piano this would have seemed sacrilegious and not representative of a serious line of instrumental engagement or to represent a lesser technique of cognitive inferiority (Hill 2005:42). In any particular instance the current pinnacle of technical mastery is accorded value, and the values create a boundary, whilst the unexplored is questionable or of lesser value.

In the use of musical instruments these value systems play out in different ways across different genres. In the case of the prepared piano the invasion of the instrument by Cage brings the ears of the listener into the space occupied by these relationships. Further, by invading the instrument the performer and composer become interrogators of the piano's accorded position. When considering the electric guitar as used in popular musics a different set of circumstances present themselves. Various extended techniques have been explored in performance (Komara 2006:63) and have become standard practice.

The ways in which these boundaries are explored in different genres creates different value judgements from other genres. For instance, classical guitarists may view the playing techniques employed by rock musicians as demotic whereas the traditional approaches of classical guitarists are viewed as old fashioned by rock artists (Klapp 191:1969). As such the norm of the concert hall practices of Western art music is contrasted with the playing of the guitar, for instance, behind the head or with the teeth. Here, the guitarist exerts perceived power over the instrument and the dominant technical approaches to it, entertaining audiences through the existing masculine expressions represented by the history of the electric instrument (Whiteley 2013:43). In certain performances the guitar is destroyed entirely, for example, in performances by artists such as The Who and Kurt Cobain, further attacking the dominant position of the instrument itself through its destruction in performance. What is of interest for my enquiry is that neither complete physical destruction nor dominance through performance style have entailed significant modification of the original instrument itself. It is important to explore why this is the case.

Learning the limits

Regardless of the learning processes by which a musician gains familiarity and mastery of their instrument the presence of the dominant discourses of organology are always present. They are present where musical knowledge of the usage of the instrument is in aural or social memory. The experienced musician has been intimately involved with their instrument and the discourses that structure this relationship for so long that they may no longer be aware of the impact that the organological structure of the instrument has imposed on them. However, a child taking up an instrument for the first time may be unaware of the limitations of a particular instrument and may, if unhindered, seek out ways of using the instrument that a trained musician may not (Kanellopoulos, 1999:183; Tarnowski, 1999:28). The experienced musician, though, after years of music education, has become constrained by dominant musical orthodoxies. Bijsterveld and Schulp query why the designs of, particularly orchestral, instruments have remained remarkably stable (2004:1). Although instrument makers have

experimented with new designs and many new patents have been published musicians consistently tend to prefer established instrumental designs. Some of the reasons uncovered by the authors in their interviews with instrument makers included the demands of composers; the cost of radical redesign; livelihoods dependant on performances with familiar instruments; political suppression; the demands for instruments to last well; the fusing of identity between musician and instrument; emotional attachment to instruments; professional pride; familiarity with handling the peculiarities of the instrument; emphasis on imitating the teacher; demands of playing a score 'correctly'; the discipline of the musical system; lack of public acceptance; value placed not only on the instrument's sonic capacity, but on its visual appeal; and the iconic symbolism of instruments.

Technological ascendance in organology

Another manifestation of these learned limits is expressed in the resistance or reluctance that instrument makers using traditional methods have displayed regarding the embedding or integration of technologies in their instruments. Even in the case of keyboard synthesisers where the sound generation mechanisms are purely technological the interface, or keyboard itself, has undergone little change. Hence the developments of weighted keyboard systems that mimic the action of a traditional hammer system in a piano. Even though developments in pressure sensitivity, typically called aftertouch, in electronic keyboards created greater levels of control (and, thus, higher expressive possibilities) this is often eschewed in favour of a weighted system. In the anecdote of the pianist I recorded, mentioned earlier, he genuinely felt that the piano was alive, and that the microphone was invading a naturally alive space. The implication is that the microphone is dead, a cold piece of less aesthetically valued technology invading the space occupied by the live performance.[36] This stems from the delineation between perceived cold instruments of science (as represented here by the microphone) and perceived living, breathing musical instruments and their invasion into an

[36] This is a long standing narrative within (especially classical) musicians' feelings on the invasive nature not only of amplification but also the impact of recording technologies. See, for example, Nicholas Cook's *Beyond The Score* (2013:349-358).

almost sacred space. In 1978 Pierre Boulez already felt that the use of technology even in recording practices was damaging to the authenticity of classical music:

> Techniques of recording, backing, reproduction—microphones, loudspeakers, amplifying equipment, magnetic tape—have been developed to the point where they have betrayed their primary objective, which was faithful reproduction. More and more the so-called techniques of reproduction are acquiring an irrepressible tendency to become autonomous and to impress their own image of existing music, and less and less concerned to reproduce as faithfully as possible the conditions of direct audition (Boulez 1978: 60).

This line between cold technology and musical instruments is ephemeral and exists in different ways in relation to different instruments, technologies and their reception within different artistic fields of practice. Whilst it is obvious that "integrating the tactile and expressive qualities of the traditional instruments with the sonic possibilities of today's digital audio techniques creates a promising perspective for instrument design" (Lähdeoja, 2008:2) to do so in practice, however, appears to present reticence.

By contrast, certain types of microphones are accorded a status approaching instruments based on their association with iconic musicians and recording. For example, consider the iconic ranges of RCA and Neumann microphones, as used by Elvis Presley and Frank Sinatra that have been visually imprinted on the musical listenership in such a way as to be directly associated with the performers in question.[37] This association is similar to the way in which a specific instrument may also be associated with a performer, as the Fender Stratocaster is with Jimi Hendrix or the Gibson SG with Angus Young. These are examples of the technological sublimation in the use of technology in performance, unobservable to the user or observer in as much as the impact of the instrument itself has on musicians, a sublimation that has accelerated as electronic and digital music technologies proliferates and their usage becomes common practice. Just as the sounds of noise turn into music over time so the

[37] See Charles Granata (2003:17-25) for a discussion of Sinatra's relationship to the microphones he used.

‘external’ technological musical device turns from being a tool to a musical instrument through repeated usage. The cyber-guitar system endeavours to exist on the boundary of this event by continually evolving and incorporating new technological elements, in part intentionally and in part through unexpected ways that emerged as a result of its development. To understand the processes of technological sublimation in instrumental evolution that the cyber-guitar also critiques, however, one needs some understanding of Western technological dependency, and the artistic interrogations thereof.

Technological proliferation within instrumental construction

Since the industrial revolution human engagement and interdependency with the machines of their making has grown with ever-increasing pace and scope. This interdependency is no longer related only to the mechanical or the medical, for instance, but is interwoven in social and artistic practice. Neil Spiller explains how “physiologically, man in the normal use of technology (or his variously extended body) is perpetually modified by it and in turn finds ever new ways of modifying his technology” (2002:73). The technologies used in any artistic expression at once further the artistic goal, but over time and with technological changes or advancement modify the artistic output itself.

Music technology has proliferated in all aspects of musical practice (Roth in Hoemberg, 2013:12). These technologies have since progressively become woven into much of the fabric of musical creation. The contemporary artist and musician is fast becoming inseparable from the technologies they use, where it was “once a container, technology now becomes a component of the body” (Stelarc in Spiller, 2002:264). Since these technologies are now extensions of the musician’s body one can say we are all now bound to the machine in a manner most easily described as a type of prosthesis. As a musician I continue to imagine that I am separate from the machine, whether perceiving my chosen instrument as such or restricting this perception to other tools such as the recording technologies vital to the dissemination of my work. In reality, however, I am not; I am as interdependent with the greater mass of technology as the pianist is with the piano.

This process of technological acceptance has been expressed in organological change through a marrying and accretion of design practices. Technological innovations were subtly brought into the field of convention through time and application. These practices were informed not only by the explorations of the sonic capacities of the instrument itself, but were additionally informed by tastes and design practices of the time as well as the newly standardised instrumental techniques and performance practices that developed in their wake.[38] As highlighted, this development of musical instruments represents one of the earliest and most heavily intermeshed interactions between man and technology. This relationship became an artistic practice of its own, with its own aesthetic concerns and values. The artisan, instrument-maker, or luthier in the case of the guitar family, became a new distinct craft with repetition as a vital element. Great luthiers were able to make copies of their own work with value placed on disciplined and refined creative work and replication yet with each 'copy' the variations were prized by the owners. This aesthetic extends into the realm of electronic instruments and in part lends value to the brand of musical instrument manufacturers such as Gibson or Fender guitars. Whilst Leo Fender, the originator of the first Fender instruments, had later no physical engagement with the physical building of each of his instruments the ascribed value of the luthier is passed on to the mass machine-manufactured instruments.

The mass manufacturing of instruments thus reveals a gap between the luthier or designer and the instrument bought by the consumer. Although the consumer buys a Fender guitar, Fender himself may never have physically come into contact with the instrument in question. This is in contrast to the more 'undisciplined' approach found, for example, in 'circuit bending' or 'hardware hacking' where the musician is physically engaged with the modification of an instrument. Circuit bending is a process of modifying existing circuits to discover new ways of making sounds from them. In my feeling this process shares more with the techniques of the luthier of the past; using unique materials to shape a unique instrument with one's own hands. It was pioneered in the work of Rheed Ghazala and documented in his *Circuit-*

[38] These explorations were, as previously mentioned, a two-way relationship between performers and composers. This two-way flow of information lasted until the early part of the twentieth century where, for a period, instruments were more standardised in terms of their principal sound generation methods.

Bending: Build Your Own Alien Instruments (2005) and in Nicholas Collins' hacking workshops and the associated book *Handmade Electronic Music: The Art of Hardware Hacking* (2006). Cook himself likes his practice to that of a luthier: the textbook, he wrote, "chronicles my evolution as a self-serving luthier during the heyday of 'chipetry'" in the early 1970s (xii). The circuit bending approach frees the discoverer from restrictions as to the instrument's 'proper' use, uses that are typically imparted by the instrument's existing design and traditions of practice. Whilst the process of design for traditional instruments often focuses on ergonomics, tonal and volume production (leading to later standardisation), recording technologies have often focussed on the reproduction of performances and their replication, and synthesis became centred largely on the synthetic production of sounds and their manipulation. As such, these three spheres of musical praxis – design, reproduction and synthesis – did not often intersect. Circuit bending circumvents their separation by bringing the creative processes into a single event and under one person's creative impulse. Specifically, the hardware hacked circuit amalgamates the instrument creation and artistic impulse into one event.

The closed or open nature of any instrument or larger musical system becomes harder to recognise once one comes into an intimate relationship through practice with the instrument or technology whilst using it in fixed state on an ongoing basis. How does one recognise whether the object in question is closed or open? At what point is the object a separate tool, apart from the user, and at what point is it holistically or prosthetically integrated with the user in the artistic understanding of such? One could ask the question, how long should a musician work with a specific item before it moves from being a cold tool, before it migrates to the nature of integrated prosthetic, or is this simply a lifelong process varying continually in the degree of integration? And if so who could accurately decide this duration?

Lawrence Kramer explains how 'thing theory' can help us to distinguish between 'objects' and 'things'. An object is inanimate, fixed, and distanced. Things, on the other hand, are "open-ended, semi-animate, intimate forms that become what they are as we become what we are. Their consistency is neither completely objective nor subjective,

but an unstable and fluid blend of both" (2011:186). If we reframe our perception of musical objects as musical things, we invite a greater 'ontological openness': "Their meaning can change their being; they are always susceptible to becoming something else altogether, to being themselves without being the same old thing" (187). Once musical systems, like the cyber-guitar, are conceived of as, and as containing, 'things' their development potentialities are open to acceleration and tactile invasion where the user can continually modify them as required.

The tenuous divide between what is typically considered a tool and an instrument is clearly a fine line. Michel Waisvisz's *The Hands* is an interesting early case from 1984 in which this boundary is central to the instrumental development. Waisvisz developed a musical instrument or control device formed around his hands, with in-built microphones and controllers.

Figure 17: Michel Waisvisz performing with *The Hands*.
(http://res.marcodonnarumma.com/project-meta-gesture-music/manager-or-musician-about-virtuosity-in-live-electronic-music-by-michel-waisvisz/)

Figure 18: Close-up of *The Hands* (http://www.tankonyvtar.hu/en/tartalom/tamop412A/2011-0010_szigetvari_live_electronics/ch04s05.html)

This instrument is worn by the user whose hands directly activate the various mechanical controllers to create sounds. The boundary line between the instrument and the user borders on full integration with the body (although it is not yet sub-dermal). Waisvisz is clear in assigning great value to a tactile relationship with a musical instrument. For him, touch, or any of the senses of the performer, is integral to an aesthetically pleasing result for the performer:

> Physical engagement – touch – adds more data streams, back and forth between the performer and the instrument. We do not understand the meaning of all these data streams and leaving out some of these streams has been empirically shown to lessen the perceived musical quality. In my personal vision for electronic music instrument design I have almost always pragmatically opened as many as possible data channels and their feedback between my body and the instruments. In the early eighties I formulated thoughts about the importance of forcing the performer to apply physical effort when playing sensor instruments. I assumed that also this effort factor was crucial in the transmission of musicality through electronic instruments. Now I think the crucial aspect of perceived musicality is not the notion of effort itself, but what we feel and perceive of how the physical effort is managed by the performer. This is also why

> laptop performance – where the performer is sort of hidden behind the screen is so un-engaging to the audience when played outside of a dance context (Waisvisz, 2003:1).

In traditional Western practice, instruments have generally been activated or played with either the limbs or the mouth – a physically observable activation. The type of organology described above proposes that tactile engagement can move beyond the traditional activators of sound, such that the rest of the body is the new field for 'extended' techniques. Instruments have, until recently, limited their field of activation to the limbs and mouth, whereas the entire body may be a potential field of activation thereby opening the instrument to other potential definitions. According to Claude Cadoz, "the instrument is a class of possible sound phenomena, and the instrumental gesture determines a particular sound event. In one way the operations of the lutist are prolonged by those of the instrumentalist, and these lead to a production of the composer's material sound object" (1998:3). By extending the field of activation to the greater body new definitions of the term musical instrument will have to be considered. Historically, electronic effects in their general application with electrified instruments have, for the most part, been applied to the signal path after exiting the instrument itself. These can be considered, in one aspect, to be removed from the instrumentalist's direct physical technique and articulation. This is not the case in *The Hands* where the human body and instrument are inextricably linked. Whereas in the majority of instruments the finger activates a single sound or control change (as in the plucking of a guitar string or the pressing of a clarinet key) in *The Hands* the multiple joints of the hand and fingers are all potential sound activators and the potential for variation is greatly extended.

Arising from Waisvisz-type practice are several questions that have informed this project: Can the interlinked aspect in Waisvisz's understanding of musical instrument engagement be considered a defining feature of human and musical instrument engagement? And if so, by increasing the numbers and variety of control potentials by incorporating yet more parts of the user's body how can this be extended further?

As discussed earlier, a trained classical performer can give a finely nuanced performance in part as a result of the years of performance and aesthetic training and through the application of continually refined techniques on what are generally standardised instruments. It could thus be argued that the variety of nuanced body-instrument gestural performance possibilities are a fundamental part of the tactile nature of human-instrument interaction itself. The lack of continuous tactile engagement in the computer and pre-recorded performance traditions stands in contrast to this, as less reminiscent of traditional musical instrument engagements. When discussing musical instrument interfaces Marianne Bech-Hansen from *Aarhus University* situates this historically:

> Back when electronic sound synthesis entered the world of musical instruments, a hitherto fundamental premise was instantly dissolved. Until then musical instruments had relied purely on mechanical technology and the unique sound and timbres of the various instruments was a direct result of the acoustic properties of physical components such as pipes, strings, membranes and reeds that made up the instrument. The advent of electronic and digital audio technologies severed the ties between the physical form of the mechanical instrument artefact and the actual generated sound, thus paving the way for sound generation liberated from the confinements of physical acoustics (2013:1).

He argues that even though many systems are available for the tactile manipulating of digital parameters they still do not provide tactile feedback to the user, making them aesthetically harder to engage with. These controllers can be assigned to any parameter, a feature that allows the performer to select any parameter they desire. However, I would argue that the variability or proliferation of choice runs counter to the intimate relationship that musicians have with more permanent or fixed objects. The sustained engagement with a control variable brings about a relationship between it and the user which develops into a refined technique over time. By removing limitless choice familiarity is an artistically valuable by-product.

These questions have informed the development of the cyber-guitar system: how can the levels of tactile engagement be maximised whilst still engaging in a holistic organological development? Historically this approach follows on from the design endeavours of the

Theremin, Ondes Martenot and Waisvisz's *The Hands*. Sergi Jordà, a Catalan innovator, installation artist, digital musician and professor at the Music Technology Group, Universitat Pompeu Fabra in Barcelona, points out that

> unlike new digital systems, in which any input parameter coming from the controller can be arbitrarily assigned to any sound or musical parameter, the Theremin is a *real* instrument; its sound is actually the direct result of the electromagnetic field variations caused by the proximity of the hands around the antennae. If acoustic instruments are built upon the laws of mechanics, the Theremin behaviour is determined by the laws of electromagnetism. Digital instruments, on their side, are only limited by the imagination and knowhow of their constructors: a substantial distinction with both positive and negative consequences (Jorda, 2002:97).

Waisvisz (2003:1) advocates for the inclusion of not only tactile engagement with the instrumental system itself, but extends this tactile nature to beyond the performer: "In my vision the magic lies in the engagement and the convergence of both our mind and body with electronic/physical instruments while interacting with other musicians preferably in the presence of an audience!" The tactile engagement encouraged here promotes a physical intimacy with the object (or rather, from my earlier discussion, 'thing') in question, facilitating its migration from tool to instrument. For Waisvisz the physical engagement has an aesthetically advantageous set of results. In my own exploration of the cyber-guitar's development I affirm that the physicality in the use of a fixed tactile controller yields results that I have found satisfying in my own performance experiences with the guitar. In other words, the bringing of controls into continual contact with the performer increases the speed of their holistic integration. By having effects controllers on the surface of the cyber-guitar and because the system's exoskeleton is continually in contact with my body the more immediate physical engagement between myself and the instrument accelerates the integration of the controllers into my own performance practice.

Such a holistic amalgamation of machine and body in the work of Waisvisz and others is one that has been explored enthusiastically in creations within other artistic practices, particularly

more recently in the domain of post-human endeavours of cyber-cultures in the work of Stelarc, Orlan and Survival Research Laboratories, for example. This particular branch of cyber-culture looks to the prosthetic extension and augmentation of the human body as its central endeavour. The performance artists attempt to "offer pragmatic models for the body in future society, and possible strategies for action, reaction, adaptation or resistance to the imperatives of information society, all within a philosophy that approaches Gnosticism" (Farnell in Sawyer & Seed, 2000:109). Farnell's reference to Gnosticism is telling: many of these artists pursue the material intervention into the human body with a spiritual vigour. The intimacy that many musicians share with their instrument of choice shares a similar enthusiasm. I have argued that in music this is not a new practice as the instrument has always been integrated into the performer's extended body, however, other contemporary artists are pursuing integration in ever-increasing ways and the link to cyber-cultural practices becomes more easily apparent. Cyber-cultural protagonists seek to create art that spotlights integration as one of the most valuable components of artistic expression. For example, Stelarc pursues not only prosthesis, but also an increasing integration of machine and body, a principle of integration that he argues has always been a fundamental pursuit (2007: 232). His engagements with the technological extension of the body through the addition of mechanical limbs and biological augmentation (such as in *The Third Ear*) bring the viewer's lens onto the physical body and its mechanistic extension. Whilst works such as *The Third Hand* and the *Ear on Arm* initially may shock the viewer, due to the presence of a surgically inserted ear or the mechanical nature of the hands, the observations made by Amelia Jones after either repeated viewing or thoughtful response reveal further insight. Jones speaks of her own experience when watching a performance of *The Third Hand*

> Far from experiencing Stelarc's (or my own) body as 'obsolete' or otherwise irrelevant or transcended, I felt *more* aware of my bodily attachment to his artistic practice – *more* and not less cathected to his technologized form. My response was immediate and identified deeply with him through an interwoven process of sensation, perception, cognition and feeling (in Smith, 2007:87).

Jones' reaction highlights that a successful cybernetic engagement in art or music is one that brings the bodily relationship with the creatively applied technology into focus, rather than simply revelling in technology for its own sake, or functioning, in colloquial terms, as a gimmick. As much as a musical instrument remains a closed system, removed from the more substantive technological engagements (or "cheap gadgets" in Cadoz's terms), so Stelarc's body, as a cyber-cultural artist, challenges this.

Stelarc asserts,

> The CYBERBODY is not a subject, but an object – not an object of envy but an object for enhancement through engineering. The Cyberbody bristles with electrodes and antennae, amplifying its capabilities and projecting its presence to remote locations and into virtual spaces. The Cyberbody becomes an extended system – not to merely sustain a self, but to enhance operation and initiate alternate intelligent systems (in Spiller, 2007:265).

This description could quite easily be applied to Waisvisz's *The Hands*, the Theremin's antennae or my cyber-guitar's exoskeleton, with the musician performing in the realm of enhanced inter-machine operation, thereby opening the body and the musical instrument to expansion in practice. Stelarc's specific viewpoint neither rejects the body nor elevates technology. Rather he argues that the body has always been a technology itself, with his art drawing attention to this pre-existing condition. This position is similar to the perspective I discussed earlier concerning the instrument as prosthesis and I recognise that each artist will have his/her own perspective on, or awareness of, integration. There is no single common position. While cyber-cultural machine interdependency is an integral part of my research and the realisation of a cybernetic feedback loop between the instrument and user has become a significant design goal, it was never a goal in itself. Rather, the technological means provided a more effective way to achieve the types of music and performance practice the project set out to create and enact.

Gestural interfacing in the cyber-guitar

Through the many different design experiments and concert performances undertaken during the development of the cyber-guitar, the exoskeleton currently in use with the instrument has proven to be the most successful design. This is particularly so because it integrates the elements of cyber-cultural practices, prosthetics and organology discussed above. These find their expression most useably in the gestural interfacing capacities of the exoskeleton.

Figure 19: Guitar with exoskeleton as used in a performance by the author. Photograph by Christo Doherty, 2014.

The exoskeleton is a modified body suit housing potentiometers and variable assignable controls (the design of which I describe in detail in the following chapter). The application of these continues to be explored in practice and through questioning the outcomes of the theoretical engagements I have outlined above. The use of various body-attached controllers and the relationships between them bring about specific nuanced and sonic changes to traditional guitar performance practice. My overriding design imperative for the cyber-guitar

was to allow for fine motor movements that do not interfere with pre-existing guitar performance techniques, and that would not be favoured over, for example, larger and often more theatrical motions. Thus, my focus has been on technological extension that allows for continuation of the instrument's dominant practice since its inception: the finest of physical motions is intimately linked to increased immediacy of act and sound. [39]

Cadoz elaborates on the immediacy of the relationship between gesture and sound:

> In 'natural' sound production by acoustic instruments, this gesture participates intimately with the physical phenomenon and directly determines some of its decisive attributes for perception and musicality. It has simultaneously a concrete function: required for sound production and a symbolic one: the instrument and its accompanying gesture are two causes that combine to produce the sound effect, and, for this reason, the sound effect bears the perceptual indices that are specifically related to the gesture. These indices may remain present and significant in the sound object when this contributes to the composition of a musical structure (1998:1).

The cyber-guitar system ensures that effects parameter changes are available to the guitarist-performer with no lag between gesture and sound. It also requires minimal physical movement, thereby distinguishing it from, for example, other video-based gestural systems for which larger movements may be necessary, movements that are outside conventional guitar performance practice. These value changes to parameters aim to be as immediate as the tactile-acoustic experience of plucking a string or playing Waisvisz's *The Hands*. These changes may still not be 'natural' in Cadoz's use of the word, where the gesture has an intimate and clear connection to the sonic event that follows.[40] Cadoz calls this area of

[39] There are many visually based systems of control generation that have been developed and form part of hyper or augmented instruments. An example of such would be the 'Talking Guitar' project by Liam Donovan and Andrew McPherson (Donovan and McPherson, 2014) which tracks the headstock of the guitar. Or the mapping of body motion by Frederico Visi, Rodrigo Schramm and Eduardo Miranda (Visi, Schram and Miranda, 2014). The use of the modified Sonalog Gypsy Midi Controller in this project was found to be the most pragmatic and effective solution within the scope of the cyber-guitar research but is not to be argued at the exclusion of visual systems.

[40] 'Natural', here, refers to an easily observable recognition for the viewer of a performance.

interrogation ‘Gestural Transducer Morphology’ and breaks the field into distinct sub-categories applicable to computer interaction. While his research is now two decades old and related to computer engagements his observations remain relevant, particularly his claim that “photocell detectors, laser beams and other sonars used to detect spatial gestures are unfortunately more often like spectacular cheap gadgets than a serious analysis of instrumental gesture in its new contact” (1998:7). I experienced this in my research for this project. In the initial stages of the cyber-guitar design I tested web-cam activation systems and both Wi-Fi and Bluetooth controllers in which levels of latency were experienced when activating controller value changes. Whilst the lag was minimal it was deemed undesirable. Cadoz’s critique of ‘gadgets’, I suggest, refers also to matters of latency and, in the case of my research, the effects of latency diminished the reading of the gestural interface. Even with this in mind, I would argue that lag itself is not the devaluing component. It is rather that the tactile interface or absence thereof is the defining aspect of instrumental engagement and through repeated practice performers can compensate for latency and even integrate it as a component of the system and as part of performance with the system.[41]

The phases I undertook to approach gestural inclusion followed this developmental approach:

1. Imagining a desired signal modification,
2. Realising its technology,
3. Experimenting either in performance, rehearsal or both,
4. Applying findings in further composition and improvisation, and
5. Application in routine real-life performance contexts.

These stages informed the various processes used in developing the exoskeleton. The imagined technologies went through various stages of development and were used in a variety of test performances, the sonic results and possibilities of which were then fed into compositions. The gestural or extended body control developed during the creation of the

[41] The early choice to avoid reliance on a laptop in the system arose out of a motivation for tactile engagement and nuanced variable changes. This choice is a reflection of my own earlier familiarity with the tactile nature of hardware effects emerging out of prior performance experience. I have recently moved the system to a software environment but find that the approaches to its application have been significantly shaped by the experience of a limited set of hardware options.

exoskeleton opens up additional possibilities to the guitarist (and, indeed, any other instrumentalist or vocalist) through leaving the entire upper body available to the performer as a potential actuator. No longer are the hands, feet or voice the singular vehicles for generating control changes. Existing guitar performance methods are furthered through new nuances, rather than by abandoning the instrumental technique (or parts thereof) or replacing fundamental components of the instrument. It is important to note that, from my perspective, the guitar is of no greater value than any other instrument, and the discoveries and technologies developed could quite easily be deployed by any other instrumentalist or vocalist, the aim being the integration of that instrument's existing body of technique. The chosen controllers and their placement have intentionally been realised in such a way that the controller suit would only be physically prohibitive for a negligible number of commonplace instruments.

The large number of variables, such as delay time, envelope filter depth and rate, that were available in the chosen electronic devices were incorporated into the instrument and could be accessed or modified with a similar sense of control to the instrumentalist's existing technique or as closely reminiscent of such. I started the build by bringing controls onto the surface of the instrument within easy reach of the performer's hands. The initial aim was to connect an optional switching mechanism to make these controls available through the suit, imagined to toggle between potentiometers on the surface of the instrument or the potentiometers in the suit. This was abandoned for pragmatic reasons of stability. The effects circuit boards that were now fixed in the guitar itself were subsequently very difficult to move outside of the guitar's body and the potentiometers were difficult to access. Even if I had elected to leave them inside the guitar and create the second set outside it the physical size of the cable that would connect to the suit would have been too bulky for ease of use. The suit was then fitted with its own micro-computer allowing its outputs to be programmed. Mainsbridge and Beilharz note that

> successful implementation of rapidly evolving gestural technologies in real-time performance calls for new approaches to performing and musicianship, centred on a growing understanding of the body's physical and creative potential. For musicians

> hoping to incorporate gestural control seamlessly into their performance practice, a balance of technical mastery and kinaesthetic awareness is needed to adapt existing approaches to their own purposes (2014:1).

The choice to move the control parameters away from a fixed cabled solution to a more programmable environment based on the exoskeleton was based on the need to experiment with them further before committing to a specific controller mapped to a specific limb, along with the aforementioned cabling concerns. I initially imagined a lack of specificity between potentiometer and circuit to be something that would result in a non-tactile experience and, in my view, a less pleasing result would be achieved if the aim was for gesture-sound immediacy. I shared Bech-Hansen's concerns that the open ended nature of a flexible software solution may diminish the quality of the performative output. As it turned out this has not been the case. I have found that the amount of time required to explore any one controller effectively results in a tactile connection between user and instrument. As one spends sizeable periods of time on the instrument (whether practising, improvising or modifying parameters) the controller becomes as familiar as any instrumental technique would.

In light of these goals the nature of the exoskeleton system is different from many other gestural or physical controllers. Kinaesthetic awareness and technical mastery operate as an evolutionary pairing that converges to create specific gestural performance techniques that are present when using the exoskeleton. For example, in the recording of the *Hymnus* performance one can hear how the exoskeleton manipulates elements of looped material. The right and left wrists change the stereo delay time. These are used in sync. The right wrist is additionally mapped to pitch whilst the left shoulder raises in sync and changes the bit rate of the facing stage right amplifier signal (5:20-6:00, chap. 5).[42]

[42] This signal is panned to the right speaker on the DVD audio.

Such kinaesthetic awareness and link between instrument and user provides a strong case for a system that is a holistic single performer system, even as instrument and user are often separated in discussion. Perhaps this is due to conventional understandings of technology as a tool, or attributable to some common scenarios in which gesturally-enabled performances are presented with two or more performers, where the instrumental performance and gestural activation are split. The cyber-guitar system, by contrast, depends on this kinaesthetic link being continually present for its ongoing evolution.

The cyber-guitar sought to amalgamate kinaesthetic awareness of additional controllers built into the instrument so that holistic integration of the control variates would replicate a learning process similar to the initial procedure of learning an instrument. Jan Schacher explains that instrumental training,

> in its initial stages at least, is mainly concerned with building this rapport between the body and the actions on the instrument that produce the sound. It serves to imprint the shape and sound of an instrument and its affordances and constraints into an adaptive, dynamic, extended and perceptual body (2013:1).

In order to achieve this, original compositions were composed, practised and performed on the cyber-guitar at each major design juncture of its development allowing me to become comfortable with the techniques and to refine them. The performances and compositions were specifically designed to interrogate aspects of the guitar's design and then, after the concert performances, adjustments, additions and removals could be made. These included using ribbon controllers attached to the neck, flex potentiometers in clothing as well as the layout and configuration of floor-based effects controllers. This has led to an ebb and flow between the processes of improvisation, composition, performance and instrument design. These often well-delineated areas have blurred in unexpected and informative ways. Ingrained procedures of taking the static instrument as inspiration for the composer's writing, intended for a performance, have been catapulted into flux and the prosthesis has become sublimated into the creative processes. If the instrument is never complete then the

relationship is no longer confined to linearity. Cadoz refers to this scenario in the following way:

> if his (the composer's) idea, his idea of the object to be produced is perfectly preconceived, with a given system, he will look for the command that will achieve it, will have to reconsider the device itself if necessary, and go back and further between the device and its use – but inversely, the device, if used in an exploratory fashion may propose objects, although not preconceived by the creator, that he may wish to use in his language (1988:3).

Cadoz's concepts frame this continual ebb and flow within a musical system. These notions break down the idea of composer (or improviser) in a manner that leads away from the division between the two and brings a focus towards the instrument in a holistic sense as a method for the generation of useful material. His assertion that the "rules of harmony and counterpoint are organisation producer systems" (1988:3) could be brought to bear on any particular formality of logic, even ones as yet undiscovered. These systems become producer systems in their own right, facilitating new capacities and new avenues of discovery. They are new producers of material. Cadoz continues:

> In fact the composer can formalise a number of rules or laws of organisation and materialise them by modelling in an algorithmic system. His relationship becomes to some extent that of the instrumentalist with his instrument. As soon as he explores the 'behaviour' of the system and chooses a given organisation at a given moment by prescribing a specific 'command', he removes the initial indeterminations proper to the system. The compositional model becomes, in his turn, a production system and sets up a new dialogue and experimentation order between creator and tool. This objectivisation of the compositional model into an automatic system is virgin territory, made accessible by the computer (1998:4).

The link between the user of systems and the creative process is one that becomes holistic, encapsulating the user's creative endeavour and system's usage in a holistic way often making the applications thereof not easily visually observable. For the purposes and aims of

this project, the nuances of gestural performance interaction with the cyber-guitar are not required to be easily observable to the auditor as is often the case in the performance practice of acoustic instruments. If the observability of the gestures is promoted over the sonic results then long-term integration of these controllers is prejudiced as nuanced performance gestures are more controllable and allow many other movements to occur at the same time. Rather, if performance on the instrument gains traction and it becomes a permanent addition to the guitar family then nuanced performance gestures will become recognisable to informed listeners over time.

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I have, in this chapter, explored the conceptual processes that framed the construction of the guitar system. As discussed in both the preceding chapters on notation and noise the research project has revealed many unconscious constraints placed on a performing musician that required unpacking to realise the end design goals. As my training was revealed to constrain thoughts on composition, improvisation and noise so the guitar's design was impacted by musicians' anthropomorphic understandings of their instruments and the limits these can place on learning processes. An understanding of how musical instruments have been intertwined with technology has yielded a realisation of how technology propels design forward and led to a practical and holistic application of gesture within the confines of a guitar system. These revelations maintained the centrality of the guitar as an instrumental system onto which additional parameters were stitched. By coming to understand the integrated nature of these elements in a holistic way a realistic set of design goals framed the building process. And because the build was undertaken at the same time that I digested other practitioners' and theorists' work in the areas discussed in this chapter the considerations of gesture and prosthetics, amongst others, shaped the organological processes and approaches of the cyber-guitar. The following chapter then focusses on the mechanics of the building process.

Chapter 4

Design and Construction

The motivations for design arising from performance history

As I discussed in the opening chapter my first instrument was the classical guitar. Performance techniques such as *sul tasto* or *ponticelli* modify the timbre from sultry to raw with sleight of hand. I learned the nuanced fine motor movement techniques required to execute such variations in timbre both through tuition and self-exploration and their mastery became a central experience of enjoyment for me; capacities which are central to any instrumental engagement. In this chapter I discuss the physical aspects of the design and construction process of the cyber-guitar and the motivations that drove them.

It was only after playing the classical guitar for fourteen years and after obtaining my Bachelor's degree in 1997 that I formally began to play the electric guitar as part of my studies in jazz. I found the dynamic and timbral range of the electric guitar to be limited or constrained, even lacklustre. In an acoustic instrument the vibrating object (in the case of the guitar the string) moves air through the resonating chamber or sounding board. In this process there is an interaction between the string, the resonating chamber and the surrounding air. The distance between the initial vibration and the resonant event is a key component of a listener's experience of acoustic instruments. In the electric guitar, by contrast, the string vibrates and the sound is conveyed to the amplifier through magnetic induction, with little direct air movement or substantial engagement with the resonating body of the instrument. The speaker may move the air, but the absence of a resonating body is distinctly different to the sound production of the acoustic guitar. The mechanics of activation to sound production in the electric guitar felt less vital to me and as if the sound vocabulary was constricted. In addition, the absence of the sensation of distance from sound source in the listener's experience of the amplified event lends a different experience. Interactions with the air, distances between sound sources and receivers, and reflections within spaces are an intrinsic part of our reception of instrumental experience. When this is not present it may create a

cognitive dissonance in the listener based on their memory of acoustic phenomena. Another avenue for understanding this occurs at extreme volumes. Heller considers that the experience of extreme volumes in certain types of performances (such as noise music or rock music) overwhelms the listener to the point at which the auditory conceptions of exterior and interior are blurred or set aside:

> An experience of listener collapse occurs when loud sound dissolves the ability to distinguish between interior and exterior worlds, especially in regard to sound and self. Sound does not only touch, it saturates and fills mental and physical consciousness, eliminating the possibility of detached listening. In a sense, listener collapse acts as a forced imposition of the type of sonic experience … it is a moment in which penetration erases our ability to distinguish between exterior/sound and interior/self, bringing both together in a single inescapable vibration (2016:7).

Whilst Heller's focus is on extreme volume the experience of an inability to distinguish between interior and exterior is also applicable to distinguishing between line (direct) signals and acoustic ones. When overwhelmed by volume the listener becomes unable to perceive their position in space. Perceived distances collapse under extreme volume, modifying the listening experience. In signals that are direct, with little intervening air in sound production, a similar absence of space is present and this, too, modifies the listening experience.

I argue that it is the listener's memory of the behaviour of the sound of the plucked string that creates a desire for an ambience not present in the amplified signal of the guitar. As Harris explains, "When a connection to a performer is established via causality (thus marked as 'familiar'), but the causality is then disrupted in some way and becomes unfamiliar, a sense of the uncanny is evoked" (2011:9). The absence of a physical resonating body or the presence of air in the resonating or amplification process is a type of absence of causality. Signal processing effects that are spatial in nature (reverberation, delay and certain modulation effects) imitate certain aspects of the behavioural characteristics of sound in physical spaces and their behaviour in air. For this reason the sounds of signal-processed

guitars (post-amp-driven distortion) create in the listener an experience analogous to acoustic instruments.[43]

Signal processing is an immediate way to modify the signal, to colour it or, in traditional terms, to change the timbre in nuanced ways that reminded me of the classical guitar. The newness of these signals, to me, was multi-layered for my practice. By creating highly modified signals I found them to be free from the types of entrenched aesthetic judgements that were such a fundamental part of my pedagogical upbringing. One could simply switch the effects unit on or off with one's foot and radically modify the sound; the challenge was to decide by how much one should alter it in a given moment. However, as the ability to modify, add or remove elements of these effects themselves in real time was not available the application of the signal changes was not as nuanced as hoped. I recall commentary from the first of my two required Master's recitals that the amount of effects added (in that case delay) was too extreme and 'drowned' the original sound. It was a fair remark, but at that stage (in 2000) I was only aware of the choice between an 'effected' or 'not effected' scenario with nothing in-between. This is a highly limited choice given that the range of timbral change in classical guitar performance is one that can be extremely subtly shaped during the playing of even a single phrase. My hopes for signal processing aimed towards a similar level of variability. It was not easy to manipulate the signals whilst playing and the effects tended, thus, to envelop the sound with a particular overall texture, sometimes to the music's benefit and sometimes its detriment. The choice of 'on or off' effect seemed crude and explains why many musicians opted to leave effects processing off altogether. In my practice at the time limitations to using effects included cost restrictions, performance ergonomics and the physical size and bulk of the units.

Over the years I purchased and worked with a wide variety of single and multi-effects processors as well as three different types of guitar synthesiser systems in order to refine timbral manipulation in electric guitar performance. In 2007 I acquired a more flexible multi-

[43] See Huang, Benesty, and Chen (2007: 15) for more on this.

effects unit, the Line 6 M13, which provided me with creative inspiration and design direction. It is a multi-effects board with a high degree of accessibility to parameters in real time, principally accessible via the optional foot-pedals although also with five potentiometers per effects unit situated on the top of the unit.[44] It was through my experience of performing with this unit that my approach to the application of effects changed entirely. Until this point signal modification was cumbersome. With multiple parameters now accessible this changed significantly. The Line 6 unit opened up the possibility for rapid application and access to a wider choice of effects, from distortions to modulation, synthesis, reverberation and dynamic effects with minute adjustments possible in the moment. Additionally, it included a built-in loop unit that was used in conjunction with the various effects and was also easily integrated into performance practice.

I began extensively exploring effects usage in The Jonathan Crossley Electric Band, which was active between 2006 and 2010. This group had a flexible line-up and performed a selection of my original music. When performing this original music I experienced greater liberty to use effects more extensively. The band toured extensively both in South Africa and Europe and released two albums during this time. Importantly, the band was an incubator for my growing exploration of music technologies in performance which the extensive touring allowed for. The Line 6 unit became an integrated part of my performance with this band. Colour changes could be made in an instant; nuances could be derived with immediacy and, thus, the 'effects machine' became an integrated and holistic part of the group's performances. Significantly, phrases and improvisatory ideas were wholly shaped through interaction with the pedal-board, and colour was applied to increasingly smaller fragments of musical invention. Rather than parameter changes being applied to long segments of invention the time between changes became smaller and smaller with the changes merging with the improvisatory event.[45]

[44] Line 6 manufactures guitar amplifiers, effects and instruments. Most effects units for guitar are housed in small metal boxes with a foot-switch. Thus the effect is switched on and off with the feet.

[45] Whilst this process was new to my practice it is not a field that was unfamiliar to me. The earlier discussed work of David Torn and Robert Fripp displays extensive use of innovative effects and looping in live performance. During this period I was also inspired by the work of jazz guitarist John Scofield. Scofield released two albums which used extensive live effects and post production, *Uberjam* (2002) and *Up all night*

This integration of the parameter changes and improvisation stimulated me to reach further into the unit for greater variety and at a point I found myself no longer content to switch between the twelve available on/off settings on the machine, and began using the individual parameter controls for each effect almost continuously. For example, after adding an echo to a note one could pitch-bend the effected signal by turning the time control on the delay.[46] By blending the ring modulator in and out of signal one was forced to improvise differently because the pitches themselves became indistinguishable from each other. By maximising the number of repeats on one of the delay units one could overload the unit and produce randomised results, not directly linked to the material played on the instrument.

To enable these effects, however, I had to get down on my knees and adjust the values with one of my hands. This made it impossible to simultaneously play using my existing technique. The Line 6 had an optional controller pedal to change pre-assigned values, but one could only apply one value change at a time when using one foot. This presented a question: Should I place the effects units on a table to allow for hand-controlled access (as many guitarists now do), or should I explore a more ergonomic and efficient means of control change? I set about addressing this question in two ways: firstly, by integrating effects into the instrument itself and secondly, by imagining ways to access additional parts of the performer's body.

For the research that resulted in the cyber-guitar I imagined, re-imagined, built and continually modified an instrument that could meet these requirements and in what follows I describe the processes of (re)building the guitar. The instrument itself is not physically a new guitar but is a modified Ibanez jazz guitar.[47] I chose this instrument because, by cutting a

(2003). As a performer working mainly in the field of jazz at the time these albums encouraged me to consider a deeper integration of effects as they occurred in a similar genre.

[46] The effect is that the pitch slides downwards or upwards with the control changes.

[47] Manufactured by Ibanez, this was an electric jazz guitar which has a hollow body, like an acoustic instrument, with two f-holes. The hollow body provides an excellent housing for the circuits.

large hole in the back of it, I could gain easy access to its inside, and the hollow body nature of the instrument allowed for ease of fitting the circuits and wiring them whilst they were mounted inside. The effects boards I settled on, after a year's investigations, were pre-manufactured boards from inside Ibanez, MXR and Way Huge effects pedals. These were chosen specifically for their small size and their use of micro components. With the support of a local retailer I was able to take effects units apart to compare the size and shapes of boards and to match these up with an imagined layout.

In exploring a variety of units, including those manufactured by Digitech, Boss (Roland), MXR, Line 6 and others, I observed that many units have multiple interconnected boards. These proved to be too large for easy insertion into the body of the Ibanez and units with single layer boards were given preference. I also investigated the possibility of building my own effects units, however, the component parts and 'bread board' configurations would be too large compared to the existing micro component printed integrated circuits produced by the manufacturers mentioned above. My final decision to use MXR, Way Huge, Morley and Ibanez units was due to their capacity to marry the quality of effects and the size of the boards. The final selection included two Ibanez distortion units, three MXR delay units, an MXR envelope filter and a Way Huge ring modulator. To this I added a Morley three-way signal-splitter as I desired multiple signal paths and multiple outputs. The Morley unit allowed for one signal input and three outputs that were able to be adjusted to different levels and switched on or off. I envisioned that three signals would be required for the phase and textural elements that would come from the looping devices, which I discuss later.

The three signal paths were configured inside the guitar as:

Pick-up, signal-splitter, distortion, envelope filter delay
Pick-up, signal-splitter, distortion, delay
Pick-up, signal-splitter, ring-modulator, delay

The boards had to be modified or circuit bent to override some of their original functionality. Each of the units was bridged and placed in an 'always on' state so as to allow the power

supply to be continuous.[48] The circuit boards were connected directly to each with cables which were soldered onto the relevant connection points and the guitar was then modified to house these modified effects. Some of the switches were left on the boards and some were moved for reasons of performance ergonomics and accessibility on the guitar's surface due to space constraints. For example, one of the Ibanez distortion units had the switch installed on the right top side of the instrument for ease of access, whilst another of the distortion units was accessed through the sound board.

I later added a microphone to the guitar as another sound source. This was placed at the front of the circuit path and a switch was added to toggle between the pickups as sound source or the microphone. The microphone's imagined function was to create a feedback loop whereby the sound created by the group (such as by the drummer(s) and bassist) could feed back into the guitar's effects matrix. This proved useful as a way of freeing myself from having to play the guitar to produce sound allowing for extended actions and interactions with the other musicians' sound whilst using the exoskeleton, and was also a way of introducing the unexpected into the improvisational process. I later removed a conventional microphone diaphragm and replaced it with a single Walkman earphone. The earphone was chosen as it is disposable, inexpensive and, because it is small, I experimented with putting it inside my mouth.[49] I found by singing 'into' the guitar I was able to provide pitch-based material whilst at the same time freeing my hands to work with the on-board effects parameters on the guitar coupled with the variations that were possible from the suit controls.

[48] Most effects boxes have a switching mechanism built into them so that when the connection to the instrument is removed the device 'powers off' to conserve battery power.

[49] The microphone was to be 'disposable' only due to the fact that it is subjected to damage when placed inside the mouth. When using a microphone with high gain effects like distortion, feedback is difficult to manage. However, by placing the microphone or 'headphone' inside the mouth this is controllable.

Figure 20: Rear view of the exoskeleton.

The body controllers or exoskeleton

Prosthetic development has been characterised by a drive towards increased interfacing between prosthetic devices and the user or wearer, where the flow of information between device and person becomes bidirectional. This is known as neural prosthetics (Akay 2007: 313). These “neural prosthetic systems share their establishment of an aggressively intimate

relationship between a specific digital technology and the nervous system of the user's body" (Cartwright and Goldfarb in Amith and Morra, 2006:139). As discussed in the previous chapter, the pursuit of an intimate relationship between performer and instrument has been a characteristic of music instrument design. The intimacy of this relationship engenders modifications over time that allows the instrument to integrate with the performer's body and mind. The cello can be viewed as an example of design-meeting-body in which the physical shape of the cello is such that it is successfully integrated into the position in which the human body performs it. Of course instruments were not always modified to accommodate the body and the body had to adapt to the instrument. In the case of the violin, an 'unnatural' bodily relationship to the instrument became accepted over time, and the instrument has not been changed or adapted to accommodate this (Nardolillo 2015: 35). Thus the prosthetic relationship between instrument and performer is an adaptive one, and the relationship can be modified in either direction. In the case of this particular research project the design has focussed on modifying the prosthetic in favour of the user.

The development of prosthetics shares certain features with the processes of instrumental design. Tactile feedback is an example of this. Recent developments in prosthetics have included feedback systems whereby the wearer of a prosthetic device can experience heat and the sensation of touch by accessing nerve endings in a residual limb (Smith and Morra 2006: 131). In this type of system the relationship is such that the feedback the user receives from the prosthetic is based on previous biological functionalities that have been lost and which the prosthetic mimics. In a musical instrument the nature of the prosthetic relationship is one where the body is augmented through the addition of a musical instrument, and the nature of the feedback is through sonic and tactile information specific to the instrument's function. In this system the outcomes of practising with an instrument are such that the user creates an expected set of eventualities and unexpected events, for instance a broken string interrupts this information exchange. The cyber-guitar system pursues the unexpected – noises and contingencies – and, thereby, challenges the expectations in the user-prosthetic relationship with the intent of extending functionality through the unexpected. For example, by the addition of the microphone to the system or the overloading of certain processors the user relinquishes components of input and parameter control in the pursuit of unexpected creative innovation.

This is not a new concept. Stelarc's *Ping Body: An Internet Actuated Performance* from 1996 is a performance piece in which the artist relinquishes control, both of a robotic prosthetic third hand as well as segments of his own body (through attached electrodes) to random informational input from the internet. The artist comments: "Random pinging over 20 global internet domains produce[s] values from 0 to 2000 milliseconds that are mapped [onto various muscles in the arms and legs] ... via a computer-interfaced stimulation system ... initiating involuntary movements" (in Smith, 2006:111). The relinquishing of control indicates a willingness on the part of the performer to allow informational control of their extended body from sources outside of the confines of the self. Free improvisers do this regularly: the musical reactions are created in the moment through interaction with external input (Kossak 2008: 35). Similarly, the cyber-guitar relinquishes control: through the addition of the microphone input and the effects manipulations and the unexpected audio interventions they create, an improvisational dialogue is opened between the instrument and user(s). Interactions with sounds made by other performers in the ensemble along with the interaction between the guitarist's body and variable inputs create a procedure where expected outputs from the system may provide the thematic material for the next phase of the improvised performance.

The initial design concepts and tests aimed to allow the performer (or wearer) the ability to adjust controller values (that were as yet unspecified) through additional parts of the performer's body not used in conventional guitar performance. The parts of the body to be used for this purpose were chosen so as not to interfere with traditional instrumental practice and, thus, were aimed at extending existing organology alongside instrumental technique.[50] Ribbon potentiometers and distance (d-beam) potentiometers offered a possible solution.[51]

[50] This has been a preoccupation of my research. Many new electronic instruments are either completely new or impact existing instrumental technique in a manner that reduces aspects of existing instrumental technique. The technologies that were interrogated in my research were ones that seemed to offer the possibility of maintaining existing performance practices as far as possible.

[51] Ribbon potentiometers change controller values when stretched or contracted. Here I am specifically referring to infrared controllers such as the Roland d-beam. There are sonic sensors which do the same job as well, however I began with infrared ones

The ribbon potentiometers were attached to the elbow joints of the body suit and with the opening and closing of the joints controller values can be sent to selected points in the effects matrix. They were also glued onto various parts of the guitar, such as the back of the neck. The distance sensors were attached to the hands, guitar or a part of the performer's body to sense distance between it and a fixed surface. This allows the wearer to create controller values by varying the distances either as a permanently active part of the performing event (as in being attached to the hands whilst playing) or by moving over the field (as in being attached to a static object). In the case of the ribbon potentiometers affixed to the back of the guitar neck I found that the fixed position confined the user to a set area on the neck, thus linking variables in controller values directly with a fixed pitch set. Both of these aimed to allow the performer to generate control data with minimal intervention, however, they required the performer to stop playing to access the control changes or be confined to specific ranges on the guitar.

Flex potentiometers were also tested for use. These are made of a flexible material that generates controller values when it is bent. These were explored both by attaching them to 'body hugging' clothing and by gluing them directly onto the performer's body. It was hoped that they would offer a way of using the knee and elbow joints as a first attempt to involve the extended body. The potentiometers were, however, found to generate erratic values that were received in no predictable way. The rejection of these based on their erratic values may seem to run counter to the value placed on noise and contingency. I argue, however, for a position where the main prosthetic interventions can be 'chosen' by the performer/user and brought into a state of user control or contingency at the will of the performer. At certain points, when the user remained still, control values were to be made static or quiet. The flex potentiometers when being used only generated random values and at no point where they completely quiet. In other words, they were not easily controllable. What became gradually clear to me was that the type of controller changes I desired, ones that could generate small nuanced values whilst still being 'quiet' or still at points, were ones that were comparable to the types of accurate changes one would achieve through using volume pots or any traditional surface-mounted potentiometer. Whether these were variable voltage potentiometers or continuous controllers seemed to matter little, and it was effectively the accuracy of 'mappable' values that became the necessary requirement. The logic behind the design

strategies on Waisvisz's *The Hands* was made clear through this testing process: if the aim is to use and map extended parts of the body in a prosthetic way then either fixed value potentiometers or mapped continuous controllers were the most effective available solution.

I began to imagine Velcro-mounted continuous controllers for my elbows and in researching this I stumbled across the Gypsy Midi Controller designed and developed by the British company Sonalog. This suit was originally designed by the company Animazoo for the purpose of motion capture for film and was then remarketed as a midi controller by their sister company Sonalog in 2006. The product was not, as far as I could ascertain a commercial success (although it received a favourable review in the consumer music magazine *Sound on Sound*) and I purchased what I was told was the last factory unit.

Figure 21: Sonalog Gypsy Midi Controller.

Sound on Sound rightly noted that the Gypsy suit was flimsy, and broke easily with the data cables failing within the first few uses (http://www.soundonsound.com/reviews/sonalog-gypsy-midi). Furthermore, the software that accompanied it (EVO) and its controller board also proved unreliable and, over time, I only retained the continuous controllers and the frame. The software also did not save the mapped values into the suit itself as the circuit had no memory and so the suit was dependant on having a computer in the performance set-up. This proved problematic as I did not wish to have a laptop present as the system was to resemble a physical prosthetic system rather than a software environment. I enlisted the help

of a software engineer, Anton Coetzee, and with his assistance we undertook to re-engineer the suit. It was rewired (or retro-engineered) and was then interfaced with an Arduino computer that was mapped to components of the original circuit board.

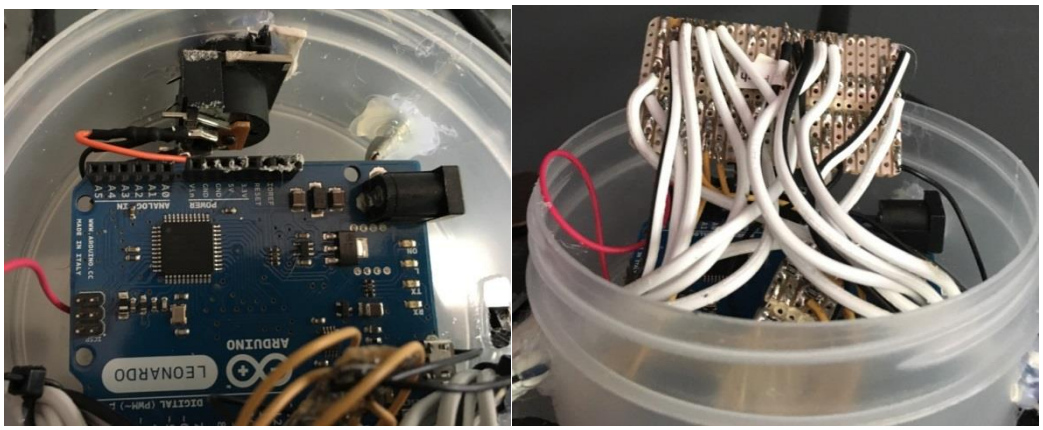


Figure 22: Mounted Arduino and modified patching.

The Arduino was configured with software that mapped the joints of my body and generated selected midi message values from 0-127 based upon the most relevant and practical joint rotations. The limits of these joint rotations were mapped through a process of 'playing' the instrument whilst wearing the suit and considering the range of motion available. The goal was that the suit movement would not change or interfere negatively with the significant aspects of my existing instrumental technique. Thus we explored, for instance, what the possible range of extension on the left elbow would be whilst continuing to improvise in an uninhibited way on the guitar neck, or what the flex range was for dipping the right wrist whilst still continuing to pluck the strings. In both examples, and indeed in all the joints chosen, performing capacity was not to be impinged upon. Once these ranges of movement were defined the joints of the suit were glued in a fixed state and the software was saved. These ranges of values could then be assigned to any external midi compatible device and mapped to controllers.

When I first conceptualised the cyber-guitar I had hoped that the external body potentiometers (ribbon, flex or CC's) would be hardwired into the variable parts of the effects built into the guitar. From an aesthetic standpoint I desired a direct tactile connection between

the controllers to the guitar whilst performing with it. In the current build this proved not to be possible, though, for reasons of performance ergonomics and ease of ongoing experimentation. If I had wired the two to be directly connected I would not have had the levels of variation currently available and, furthermore, the most useful joints would only be assigned to a single parameter. By compromising and having no direct physical connection between the guitar and suit I have created a flexible effects usage scenario. A future iteration of the instrument may allow for a direct integration of the two prostheses.

On live looping in system design

I began working with commercial phrase samplers or loopers as soon as they were available in South Africa. I gave my first public performances with the Lexicon Jam Man phrase sampler in 1999, but was already experimenting with types of looping through delay pedals earlier than this. My initial performances with the Jam Man included an approach to the musical material from an improvisational standpoint or in the aforementioned tradition of live looping. Compositions were written with portions (phrases or longer chord progressions) that were recorded live and then improvised over.

During the period of The Jonathan Crossley Electric Band I began using the looped material in two distinctly different ways from how I had previously used loops. The M13 mentioned earlier had a stereo loop system built into it, which could record after the internal effects parameters were applied thereby capturing processed material into the loop station. It could also reverse the material and play it back at half speed or an octave lower, and then one could record on top of this as well.

Aside from textured material in the tradition of Torn or Fripp I also began to explore rhythmic loops with the inclusion of an intentionally accidental rhythmic glitch: I played what would be tempo based loops inserting errors on purpose. I found that these processes produced some inspiring improvisations particularly with the drummer Jonno Sweetman for

whom the ‘illogical’ nature of the loop points seemed to prompt aggressive counter-groove performances.

The signal path of my looping practice had a limitation: the pad or loop elements fell after the guitar signal and after the effects patches whereas I desired a before-and-after possibility for looped material. I began using a configuration in which I placed a loop unit in front of the Line 6 in the signal path so that the looped material went into the Line 6 along with the signal of the guitar being played live. This was a development that emerged from the active modification of signals as they passed through the M13, with both a live signal and a looped signal available for modification in real time. I then had the further option of recording this blend after the effects which meant that the multiple materials played back such that the tempos of the various loops were completely unrelated.

As mentioned earlier I was inspired by the work of Torn and Fripp but also by the phase compositions of Steve Reich and La Monte Young. I imagined a loop configuration that would include processes whereby two or more versions of the same musical fragment would drift or be moved ‘out of phase’ with each other, hoping the resultant interplay would yield new layers of musical interest. This was explored through extensive performance and improvisation and informed the design successes and failures discussed here.

As a design motivation I endeavoured to find a way to marry the phase shifting aspects mentioned earlier and the improvisational practices fostered by a single loop system. In other words, the loop system had to be able to record a single improvisation, allowing overlaying of additional tracks of material, and to allow for various types of modifications to the different looped segments.

In addition to the desire for options for non-synchronous rhythmic materials I wanted to introduce a pitch-based phase element as a potential option. Thus the design would have to include three loop systems that could record simultaneously and include the option of tempo

variations on one or more units and pitch variations on others. I hoped that this would yield the possibility of phase and pitch shifting whilst still being able to function in a wholly improvised scenario. I envisaged a situation in which the improvisations of two drummers, each playing in relation to the perceived tempo generated by an improvised loop, could gradually drift out of phase. The process of phase shifting or multiple tempi is not only derived from the early phase composition compositional work of Steve Reich or Philip Glass, but additionally finds inspiration in more recent 'intelligent dance music' or IDM. For the T.E.P.P. *Hymnus* concert of 2014, which included two drummers, I hoped to introduce a multiple tempo approach within an improvised setting. The loop matrix was employed to afford a type of machine intervention through chip tempo drift or via an intervention by the performer in the form of tempo and pitch variations.[52]

The signal path for the loop system used for the *Hymus* recital was routed into three different loop stations from the three outputs on the guitar. Each of the three loop stations had the 'record/overdub' switches removed from the circuit, which were then reconnected to a single switch that accessed the functionality of all three simultaneously. One of the stations retained the initial loop as a fixed loop, the tempo could be adjusted via the second one by the performer, and the third one's output was routed through a Digitech 'Whammy' pedal. The pedal allows for a variety of pitch shifting options across a two-octave span, enabling loops in parallel intervals to be realised during a performance, as well as free pitch sliding. One of the loop stations also contained a tap tempo delay option that could be introduced to either augment or undermine the tempo of the loop(s). This system design was never successfully employed in performance as the digital audio interference that was created by linking the units rendered them unusable. The audio path was too noisy and the drift in tempos so negligible over a short time that in a live improvisation context the intervention was not creatively useful. The simultaneously triggered loops did drift by tiny amounts but took hours to do so over many repeats.

[52] No two computer clocks run at the exact same speed although the deviation is negligible. I imagined that if a rhythmically complex loop was recorded at the same time on two different machines with two different clocks then eventually they would drift out of time with each other

The ‘failure’ meant that I abandoned this process and explored a different solution. I connected three separate loop devices to the outputs of the guitar that are triggered individually and, because they do not record the same fragments, can only contain different material. Two of them are directed into the M13 that has a single stereo loop recorder. At the point at which the non-synchronised loops overlapped in a way that I was satisfied with I then recorded this blend into a single stereo loop. In this way the original two fragments played over another blend of the fragments on the output stage. The M13 looper can reverse the materials as well as halve the tempo and pitch, creating interesting textures which are dual unsynchronised mono loops.[53] Further, the original two loop segments play back through the effects of the M13, as well as a variable pitch shifter and bit crusher, allowing manipulation via the exoskeleton recording into the stereo loop. These segments are also connected to the exoskeleton system and can be sonically manipulated in an improvised way. The resulting textures are sonically far removed from phase-based compositional approaches or the types of looping approaches mentioned by Parker (Cox & Warner, 2010:243), even as they draw on aesthetic approaches derived from these techniques.

The cyber-guitar system thus currently contains three components: the effects-enabled guitar, the exoskeleton that manipulates external effects components, and the multi-layered loop configuration. As with any design project arriving at this stage of the cyber-guitar’s form has involved a marrying of imagined and desired outcomes with technical feasibility and performance functionality in an attempt to create a usable system that does not require excessive assembling. The aim was to create a recognisable and practical instrument system.

Building the guitar

The construction of both the instrument and loop configuration were processes of experimentation and in this section I document this photographically and by discussing

[53] This can be heard in the first section of the recorded *Hymnus* performance from the start through to around the 3’20’’ mark. The guitar strings are brushed initially and looped generating a bed of looped sonic material in the style of David Torn. These layers grow gradually in density throughout the first movement and then are re-recorded onto the other loop devices later in the signal chain. The exoskeleton modifies components of these (particularly with pitch shifting in this example) via the wrist controllers during the movement.

aspects that motivated these choices. I discussed my reasons for selecting the Ibanez guitar and various effects units earlier, and after settling on the selection of manufactured boards and the standard factory made guitar I began to prepare the instrument and the effects. [54]

Preparation process

The first task in the preparation process for the guitar build was to disassemble the effects pedals so as to assess the size of the circuit boards, the connections necessary and how the circuits would need to be modified to operate inside the guitar effectively and permanently. A number of key questions were to be considered:

1. How should the circuits be positioned for manageable access within and from the outside?

2. Would the structural integrity of the instrument survive this number of modifications?

3. How should the circuits be supplied with power?

4. Would there be audio interference between the circuits and the individual power supplies once these circuits were removed from their housings?

5. How would the initial build affect later additions such as the microphone, body controllers, bit crusher and selector switches?

The first concern, relating to the position of the circuits, was determined by the available space on the front of the guitar and by the position of the strutting, the pick-ups and the guitar

[54] In Collins' (2006) and Ghazala's (2005) books on circuit bending the area of focus is on toys and other circuits such as the infamous Texas Instruments 'Speak and Spell'. Whilst I have done much work in this area I confined the work in the cyber-guitar to pre-existing manufactured boards for the reasons of cost and size. Building the effects on breadboards myself made them too large for use in the guitar and thus 'bent' existing boards were preferred. These 'bends' didn't modify the parameters in any extensive way but rather the principals of circuit-bending allowed the design constraints of the system to be realised pragmatically and inside budget.

controls.[55] Decisions about the placement of the circuits were made on the basis of available space within the housing matched with ergonomic placement on the sound board as opposed to ideal design or visual concerns. Apropos the second question, because the positioning of the pedals was possible without modifying any trussing this concern fell away.

Building the guitar

As I already owned an excellent Gibson ES-175 jazz guitar it was a first choice for the hollow body to house the system. However, I found the full size cavity too bulky and was worried that it would be difficult to play. Ibanez and Gretsch produce a range of three-quarter size cavities, and an Ibanez was available and was a cost effective option. Given the experimental nature of the project and the uncertainty of the final cost an affordable guitar body was an important initial consideration. Once the instrument was acquired I took it to a guitar technician so that we could cut an access point into the back of the instrument.

Cutting of back of guitar for access to interior

Figure 23: Cutting of the Ibanez guitar.

[55] The soundboard and sides are supported by internal strutting. Modifying these structural supports was avoided.

The rectangular access area cut into the back of the instrument provided easy access to the interior for the insertion of circuits, wiring and controllers. In figure 24 notice the two existing pick-ups and the two beams of strutting, both of which were retained.

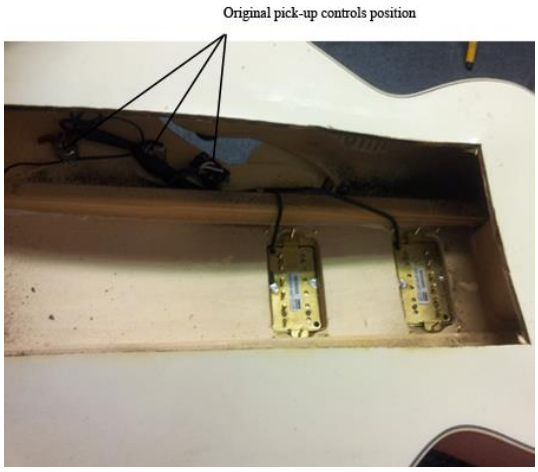


Figure 24: Original pickup and tone locations.

Fitting the components

The original guitar controls (two tone controls, two volume controls and a pick-up selector) were set out by the manufacturer in ergonomic positions across the bottom of the soundboard. For the cyber-guitar they were moved closer to each other on the very top of the guitar surface, close to the neck position and wiring was extended where necessary. The final position utilised the least amount of space and was close to the imagined position for the signal selectors.

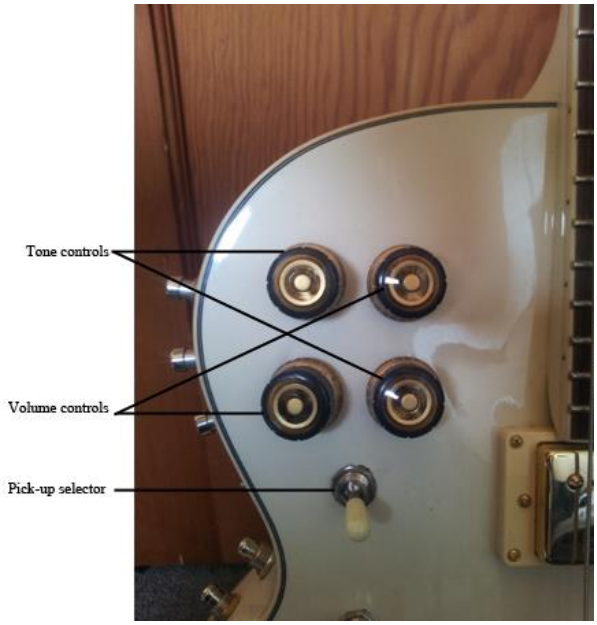


Figure 25: Repositioned tone and pickup controls.

I then had to ascertain whether I needed to remove the circuit boards of the effects pedals from their housings. In figure 26 one can see that removing the circuit boards was necessary as the first seven effects I aimed to insert into the Ibanez body would otherwise not fit. So all the circuits were removed from their cases and the two distortion units pictured below in figure 26 were stripped and mounted via screws on the strutting.

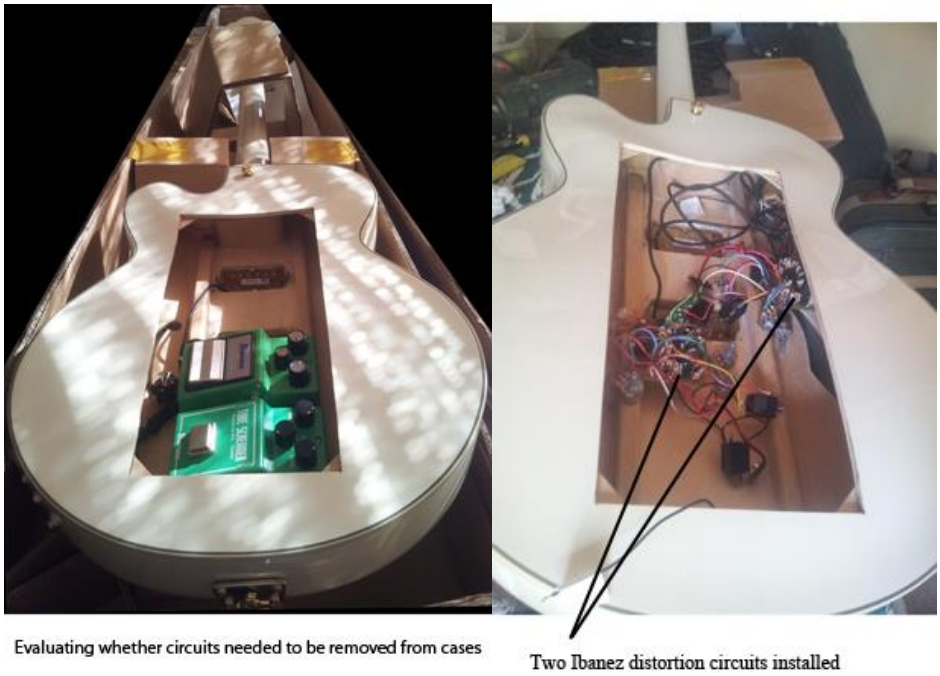


Figure 26: The original casing size of the two Ibanez drivers compared to after their removal from their casings.

Following the distortion circuit installation, I wished to install the three MXR delay circuits. I wanted these three units to be in close proximity to each other for ease of access to their controls. The lower part of the sound board was the only area large enough to accommodate all three. They were carefully positioned and then, one by one, the required holes drilled into the guitar's body.

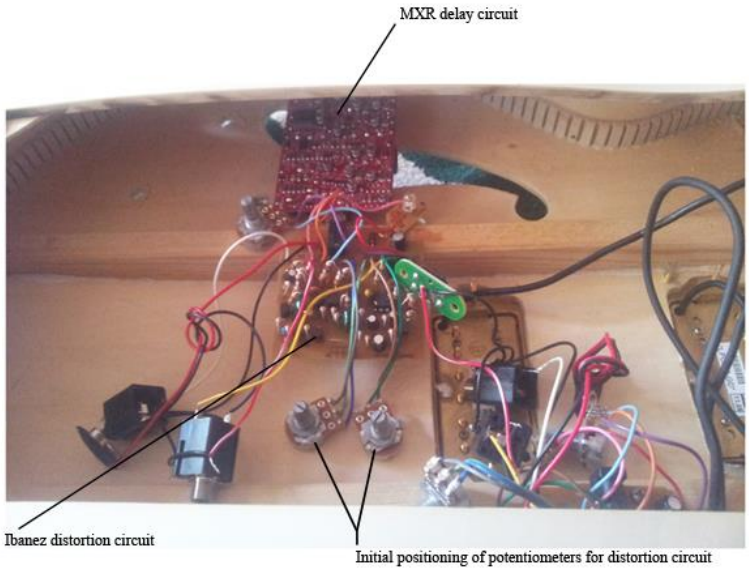


Figure 27: Positioning MXR and other boards.

Figure 27 shows the first MXR board attached to the guitar with space allowed on the right and left of it for the subsequent units. Where possible potentiometers were fed through the existing f-holes of the guitar to save space and reduce drilling.

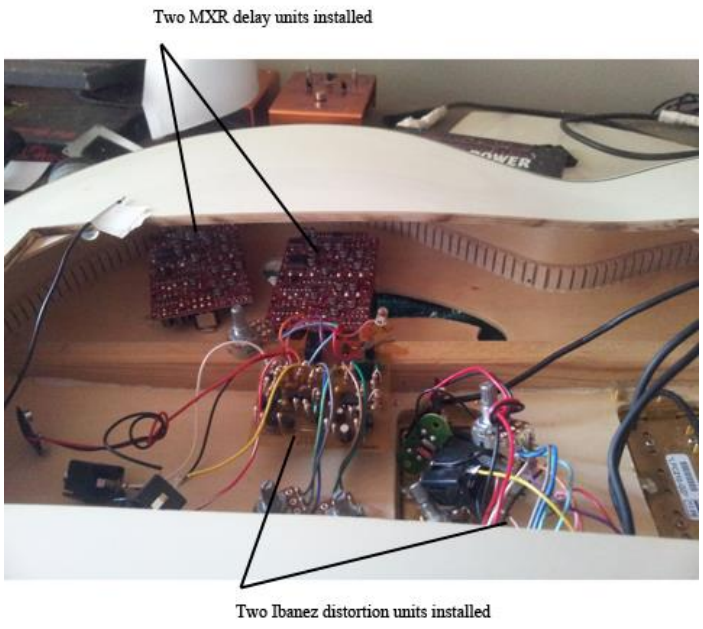


Figure 28: Two mounted delay circuits.

Figure 28 shows the first stage of installation of two delay circuits as well as the potentiometers from the Ibanez distortion units, glued down in temporary positions so as to allow soldering.

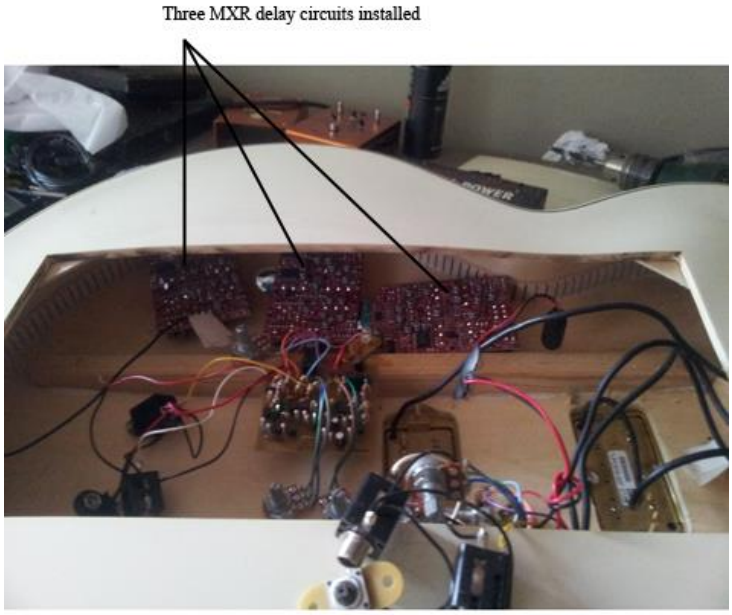
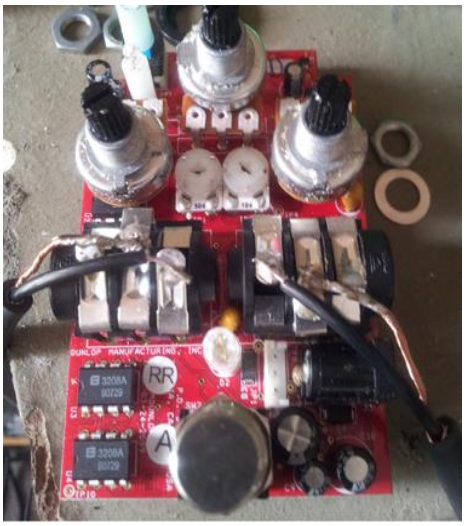


Figure 29: Three mounted delay circuits.

At this point all three delay circuits were fitted, although they had not yet been modified or connected to power. I chose a mains-based power supply system over batteries as the on/off system employed by the pedals was activated by removing or inserting the jack inputs. As the circuits were to be permanently wired together this system had to be bridged into an ‘always on’ position and batteries would run down quickly.

Modifying the MXR board to remain 'always on'



Modifying circuit boards so as to remain 'always on'

Figure 30: Simple bridging of circuits into an 'always on' state.

In the figures above one can see the first two points on the jack input bridged across the negative positions of the jack insert. These two positions were permanently soldered together and connected to the ground. The positive point was permanently soldered onto the circuit board as well. All audio connections were made using co-axial shielded cable for noise reduction. Once the circuit boards were permanently connected they were re-fitted into the instrument with potentiometer controls in the most functional position on the front of the guitar's soundboard.

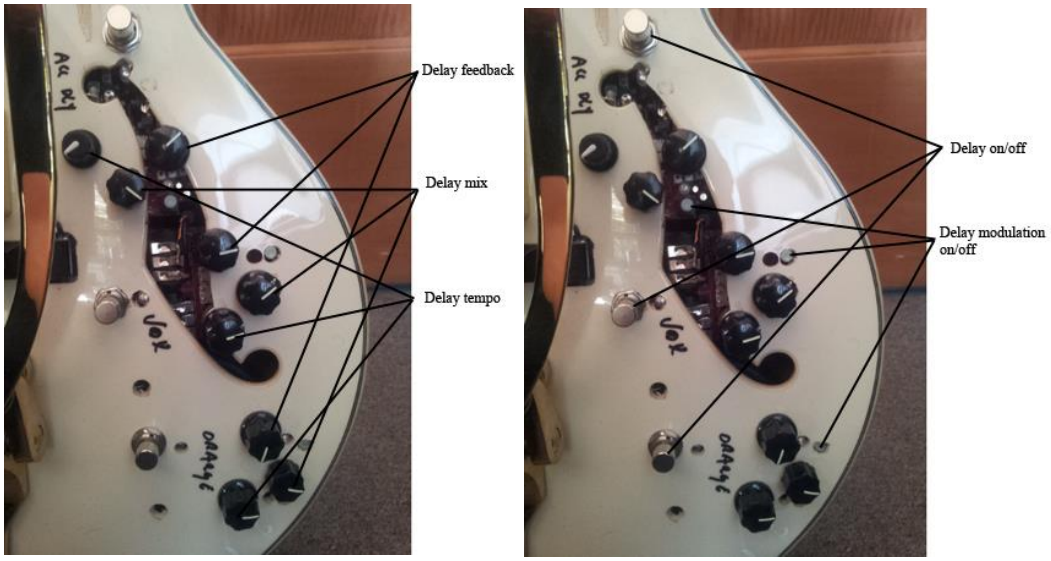


Figure 31: Position of the three delay units and their controls.

After the delay circuits were fitted the ring modulator and envelope filters were installed next. For reasons of surface space and to separate the different types of effects controllers I installed them on the opposite side of the sound board to the delay units (see figure 31), still allowing for access and unrestricted movement of the performer's arm. The delay controls were tightened in position with buttons refitted as power was supplied.

Figure 32: Delay units active with ring modulator and one drive unit mounted.

After this stage of the installation power was supplied and the three outputs for the output selector circuit were connected. However, I found that with the output of the pick-ups directly wired onto the system of circuits there was audio (impendence) cross-talk between the units. For example, enabling an effect on one of the signal paths would affect the output of a separate signal path. The need for a signal splitter became apparent, as it would take the output from the pickups and electronically separate the signals as well as allowing for their adjustment in level. This also offered the option to switch each of the signals on or off, which was highly advantageous. The problem was that the guitar's internal surfaces were already crowded with little space on which to mount the splitter. The only viable mounting position was on the back of the access plate that had been cut out in the initial stages.

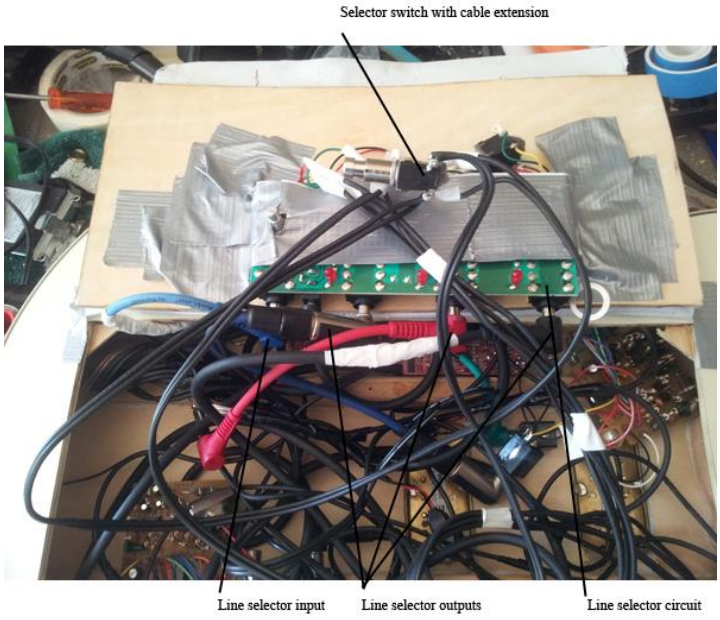
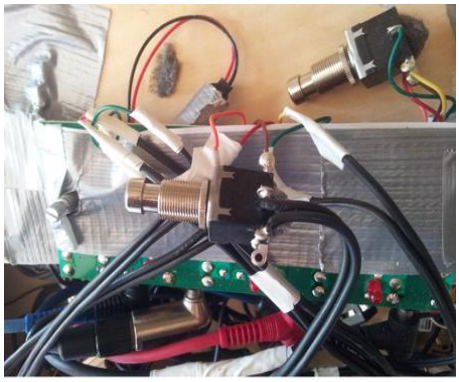


Figure 33: MXR three-way signal splitter patched with extensions fitted to selector switches.

In figure 33 one can see the line selector, with inputs and outputs connected. One of the on/off switches has had cable extensions attached to allow it to be affixed to the guitar body. Each of the three switches had to be extended to allow for mounting elsewhere on the instrument.



Extending line selector switches

Figure 34: Extending the line selector switches and mounting positions.

The on/off switches for each of the three signal paths needed to be immediately accessible to the player so as to enable or disable a signal with ease. I decided that these should be mounted on the top arch of the instrument, but this presented a problem with regard to the ring modulator and envelope filter circuits as the access points for the switches would be extremely close to them potentially creating interference. Fortunately, they could be separated from their circuit, mounted individually and insulated so that they would not touch the circuit and could, thus, be installed effectively.

Slots for line selector switches

Figure 35: Line selector switch positions.

Figure 35 illustrates the installation of the first selector switch and the holes for the remaining two switches. The installation of the line splitter solved the impedance and cross-talk problems. A position and circuit also needed to be chosen for the microphone. A selectable dynamic microphone was to be installed into the circuit layout prior to the line selector, which would allow ambient sound to be fed into the guitar effect system. To this end the microphone was mounted into a section of the top f-hole in the instrument and was wired into the signal path before the signal splitter. A performer would thus be able to toggle between microphone and pick-up inputs with a toggle switch mounted next to the line selector switches.

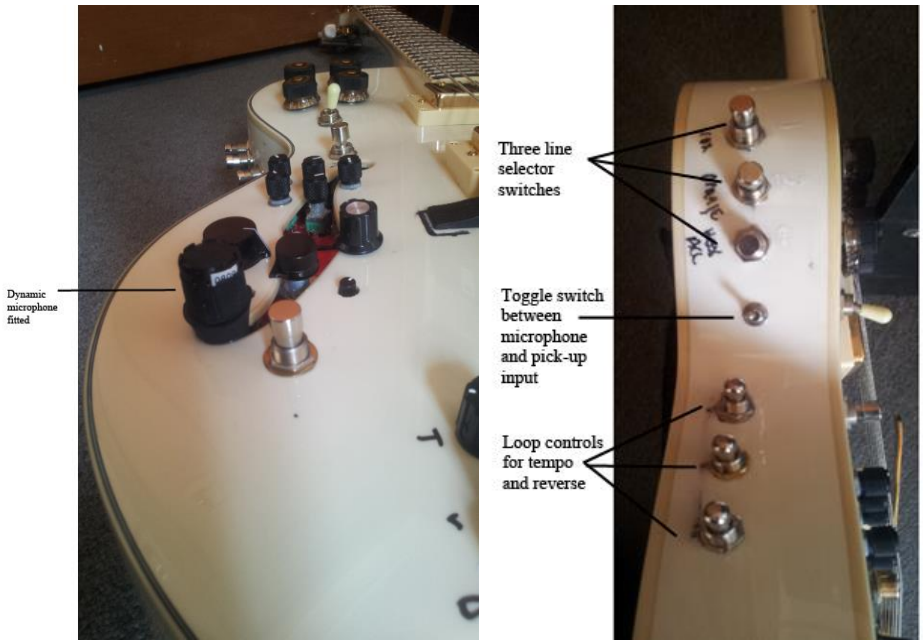


Figure 36: Initial microphone placement and switches for microphone toggle and loop triggers.

Power is supplied from an eight output nine-volt AC-DC converter and, as a result, eight different DC supplies come into the instrument. The converter is positioned outside the instrument due to its size and weight, and the eight lines are standard, two-way electrical flex cable, joined together in a plastic conduit. They enter the instrument on the lower side just above the three-quarter-inch jack outputs and are held in place by a small plastic clamp.

Figure 37: DC power supply cables for the internal circuit boards.

There was some concern during the construction as to whether the exposed circuit boards inside the instrument and the cable connecting these various boards would pick up interference or 'power hum' from the lines of flex cable powering the circuits. For this reason, only co-axial insulated cable was used to interconnect the various circuits and no interference has occurred.

Configuring the loop system

As discussed earlier the loop system I envisaged required three looping devices able to record and play back material simultaneously and in a live performance environment. In addition, one of the loop systems would need the capacity to time stretch (to slow down or speed up the fragment without affecting the pitch) or compress a live recorded loop; another needed

the capacity to pitch shift one of the loops; and at least two of the systems needed to be able to generate a click track. Once again, instrument size and ergonomics played a key role in the choice of systems.

Two Digitech Jam Man Stereo units were chosen both for their size and the capacity to generate click tracks. A third different Jam Man Delay unit was added to this, as the third loop system did not require click track capacity and the addition of a further tempo controllable delay unit was desirable for the introduction of phased material. As mentioned earlier a Digitech Whammy pedal was added to one of the loop system's outputs to allow for the changing of pitch. This pedal can variably alter the pitch of a signal in controlled increments or freely up to two octaves below or above the given signal's initial pitch. The entire system needed the ability to stop and start recording simultaneously whilst having the ability to stop each loop individually. The time stretching ability needed to be accessible from the instrument and, as mentioned in the section on the construction of the guitar, the circuit to control this tempo was installed into the guitar.

The initial objective was to trigger the looping process simultaneously with one switch and, thus, the record switches were removed. These were connected to the circuit board by three contact points, which were connected to cable extensions that ran outside each of the cases. A single switch was then mounted in a box and all three points from each circuit were attached to the relevant points on a single momentary switch. This created repeated system failures. Not only did the individual units behave erratically, triggering random functions, but they also were asynchronous. A further complication arose when they were connected to amplifiers. Once the signals were amplified there was audio signal interchange between the different units and system noise was heard loudly through each amplifier.

First loop station with REC/PLAY/OVERDUB switch removed

Figure 38: Digitech Jam Man with the record and overdub trigger removed.

Through testing it was ascertained that these problems arose from short circuits between the units and a more rudimentary approach was required. Each of the three cable extensions were re-attached to the individual switches. These were then installed into a plastic box and joined together via a non-conductive epoxy material. This proved successful in that one could trigger the looping process without interference. A usable system had now been developed and this was debuted in the performance *What if the machine spoke back to you?* in August 2011.

Inside the grouped record/play/overdub switch

Figure 39: The inside of the plastic box holding the three loop device triggers from the three separate Digitech loop stations.

In figure 39 one can see the inside of the plastic box with the three switches and their cable extensions attached. Below, in figure 40, is a view of the top of the switch box. The switches are joined together with epoxy and a plastic cover plate is attached to all three. The cover plate allows the three units to activate together when depressed.

Three way grouped RECORD/PLAY/OVERDUB switch

Figure 40: Plastic box housing three switching mechanisms, linked with epoxy.

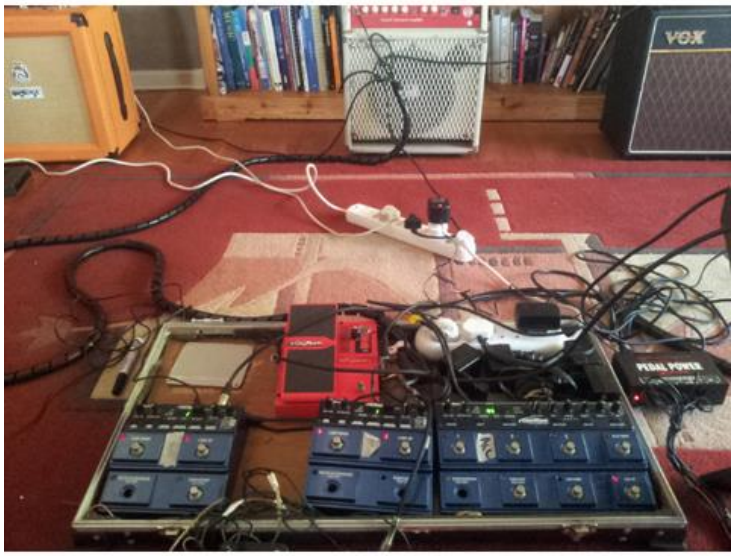
Once the three units could be triggered together they could be used in performance. In the first performance the drummer Justin Badenhorst was able to receive and perform to click with ease. A small mixing desk was set up next to Badenhorst so that he could manage the click feed from the loop matrix as required. In both rehearsal and performance it was found that the drift between the three loop units, whilst minute, provided some interesting creative contingencies that could be responded to.

I experimented with a wide variety of configurations of the various effects during the building processes. I also introduced and removed different units from this configuration as the creative and technological project evolved. At this juncture the three loop stations' outputs were connected to three guitar amplifiers with an Ottomachine Biscuit in line. The latter is an eight-bit bit-crusher with additional step filters, wave shapers and delay features.

The colour that the unit adds to the signal is of a ‘digital’ sound, characterised by a graininess that further abstracts the original guitar sound. I originally hoped to insert this unit into the guitar; however, the circuit was too large to fit in any of the remaining available spaces inside or outside the instrument.

Figure 41: Ottomachine Biscuit.

Due to the extreme signal modification capacity of the Ottomachine I was reluctant to exclude it from the signal path simply because it could not fit into the shell of the guitar. In future I plan to explore mounting it onto either the guitar strap or developing a clip-on mounting system on the exterior of the instrument. At present it is mounted above the loop system.



First testing of 3-way loop system on three amplifiers

Figure 42: Testing of the linked Digitech loop devices.

Figure 42 shows the three-way loop system with three amplifiers in the background. The three amplifiers deployed here are an Orange Tiny Terror, a Vox AC 15, and a SWR Strawberry Blonde. Two of these (the Vox and Orange) are electric guitar valve amplifiers, while the SWR is an acoustic guitar amplifier. The inclusion of a different amplifier type was explored because one of the guitar's three outputs does not use distortion or drive effects but passes through the ring-modulator. The extended frequency range of the acoustic amplifier represented the frequency range of the effects generated by the ring modulator better. In subsequent performances direct boxes were also used. A wider variety of frequencies are, therefore, created through the addition of this amplifier.

Building the exoskeleton

Building the exoskeleton involved the adaptation of the aforementioned Sonalog Gypsy Midi Controller to the creative requirements of the cyber-guitar system. Initially I imagined that the various potentiometers that were part of the effects boards inside the guitar would be

connected to a body-enabled potentiometer system. As mentioned, a variety of these were tested, including d-beams, ribbons and others. However, when I first read about the Sonalog Gypsy Midi suit it seemed like a perfect solution. From the adverts for and articles on the suit I mistakenly thought that the software that shipped with the unit was used to configure the stand-alone suit. This was not the case. On receiving the suit I was confronted with having to couple it to a laptop during performances, an aesthetic position I had wanted to avoid. I also found aspects of the suit's construction to be weak as the cables connecting the unit's various joint-mounted CC's were corroded and failed almost immediately. The suit's joints were fragile and could not be tightened enough to remain in a fixed position such that the range of values continuously changed.

For these reasons I retained only the suit's frame and the CC's. I rewired, removed the circuit board, and placed an Arduino into a simple plastic housing on the back of the suit, testing the range of motion specific to my body and the way it interfaced with the guitar in performance. This was mapped and saved on the Arduino and then the joints were tightened into these positions and permanently glued in place with epoxy. Thus the CC ranges were specific to my body and performance practice. Through practising and performing on the instrument with the exoskeleton a performance technique began to develop. These techniques developed in two directions. Firstly there were the smaller motions on the wrists and shoulders mapped to pitch and frequency on the bit crusher. These motions allowed me to continue playing the guitar and by flexing the wrists the parameters could change significantly. Secondly there were larger motions from the elbows and forearms principally mapped to stereo delay time for the *Hymnus* concert. These allowed me to aggressively modify delay time but I had to let go of the guitar to do so. One hand could continue sounding the instrument through hamming on with the left hand or plucking with the right, whilst the other could modify the left or right assigned delay parameters. As these potions and applications stabilised the suit it could be stored in a fixed and immediately usable state between performances.

Figure 43: Left wrist joint being used during a performance. Photograph by Christo Doherty.

In figure 42 the narrow range of use can be viewed by considering the left wrist of the performer. The range of motion for this CC is defined by the motion of performance mapped across a tiny fraction of the available CC values and all the performer needs do is push the neck of the guitar slightly away from the body to compensate for the suit's presence.

At work here is an important principal in understanding the exoskeleton as an organological extension of the guitar rather than as a separate device. By using only ranges of motion that are available to the extended body that do not impact on traditional performance technique the exoskeleton fuses itself with the greater organological guitar system including the performer's body. This opens up the device for inclusion into other instruments or instrument systems as it does not require the change of existing performance technique, other than getting used to wearing the physical exoskeleton. If this was used by, for example, a pianist, the exoskeleton could be absorbed into the pianist's existing practice without inhibiting the user through a re-mapping of the CC ranges. This brings the availability of nuanced fine

motor skills to the user through integration into an extended prosthetic system with only minimal learning processes required and without abandoning any significant part of the existing instrumentalist's capacity. The adapted Sonalog Gypsy Midi Controller has, therefore, been the most productive realisation thus far of the evolutionary and holistic design goals of this project.

The ribbon controllers, d-beams and other controllers were abandoned as they required the user to, for the most part, either give up certain techniques or have reduced capacity to use techniques that they had previously learned when applied to the instrument in question here. This is not to suggest that the inclusion of such types of controllers would prejudice other types of instrumental technique in a similar way, in fact the length of the ribbon controller tested in this research would map perfectly to the back of a violin. And there are many examples of research projects that explore controllers in a similar manner. The Yamaha Corporation released an exciting example with the MIBURI body suit as an intended commercial venture in 1994. Lindsay Vickery then adapted this for use with STEIM's (STudio for Electro Instrumental Music) interactive video software Image/ine (2002: 1). A more well-known popular application is Imogen Heap's gloves, although these are not principally designed for interaction with an instrument and rather allow for accessing and manipulating a software environment. Whilst both of these examples used material worn by the user in the manner of clothing my modified Sonalog Gypsy Suit yield controllable results whilst allowing me to play the guitar in a conventional manner.

Figure 44: The rebuilt exoskeleton.

The system was rewired for a third time with generic grade flex electrical cable (see figure 44). The original wiring from Sonalog was a type of computer VGA cable that was not designed to handle the extensive movement and physicality that is now being demanded of the suit. The second attempt involved two types of co-axial cable, however, I found that this also perished and cracked with repeated motion.

Figure 45: Exoskeleton elbow, shoulder and wrist joints.

The original wiring over the CC's had heat-shrunk rubber joints, but due to the solder points cracking and coming loose I decided to leave these exposed so as to allow for swift fault finding if required. Leather and fabric tubing now cover the cables and arm expansion areas so that they do not tangle and are protected. These are simply sealed with Velcro to allow easy removal and re-attachment.

Moving forward

The field of gestural interfacing and new instrument design is currently an extremely vibrant area of research and development. Some of the field's many platforms include the annual conference New Interfaces for Musical Expression, the Margaret Guthman New Musical Instrument Competition located at Georgia Tech, the Ars Electronica competition, and McGill University's music technology courses. Much research has been undertaken on the development of new instruments, such as Dan Trueman's Bowed Sensor Speaker Array, a modified type of violin-based practice, and 2016's Guthman competition winner, Ken Butler's Golf Club Sitar. What differentiates my research project is that a primary goal has

been to maintain all aspects of the instrumentalist's existing technique while extending the instrument in ways which do not impact on this practice.

This process continues and the current plan involves working with a luthier in an attempt to re-fit the entire electronic system of the guitar, much of it currently external, into a solid body instrument for easier transport and quicker set-up and access during performance. This would include a battery-driven option for the internal effects as the cabling is cumbersome. It is also my intention to fit the guitar with wireless transmitters for the multiple outputs so as to make it cable free. For the same reason it is desirable that the exoskeleton communicates by Wi-Fi or Bluetooth. An attempt at this using an X-bee Wi-Fi circuit was already made but the packets of MIDI information were too large and delayed for continuous control. In other words, the wireless technology attempted compromised the instrument's functionality. But I am exploring alternative solutions to this.

Another avenue for future investigation is the possibility of software integration with the system. I am also currently investigating incorporating a software environment into the system in ways that allow for an approximation of physical control of the cyber-guitar's performance that is so central to the instrument I imagined, designed, and built, and on which I perform. The absence of hardware engagement may have some as yet undiscovered aesthetic limitations, but will enhance the speed of setting the system up for live performance due to the absence of cabling. I imagine these limitations only due to previous experience, as software effects have not behaved in the tactile ways that hardware has consistently done. The software enhancement may be attached to the wireless re-working of the system with the computer stationed near the mixing console, for example, as I remain reluctant to have the guitarist bending over a laptop during performance. The screen, I feel, introduces a barrier between the audience and the performer, and importantly alters conventional performance practice. By contrast, the thrust of my research has been to (re)build and extend the guitar in ways that allow for the continuation of use of the life-long performance skills guitarists acquire while greatly expanding the guitarist's means of expression and the instrument's sonic palette.

Conclusion

The *Hymnus* recital presented the full system in performance for the purposes of examination. The presentation was intended to display the intersection of the three main areas this research has considered: the impact of different types of notation, especially graphic-inspired notation (evident in the score of the *Hymnus* composition), engagements with noise (via the cyber-guitar system and the interactions with the collaborating musicians and monitoring interventions), and the nature and impact of the machine interfacing (through the configuration and design of the cyber-guitar, looping design and the exoskeleton). This performance could have been conceived of as the sonic conclusion of the project. However my reflexive considerations have encompassed more than this single performance. And since the *Hymnus* concert the use of the system has presented other encouraging results that evidence a growing integration of the system with aspects of prior practice and suggest directions for future use. Subsequent performances with the instrument have been, in my mind, increasingly successful in their application of the outcomes of research in a way that the *Hymnus* performance was not.

To draw a closed set of conclusions from the *Hymnus* event would also run contrary to my desire to continue to develop the system; and to think of the system as an open one. The outcome of this research project might rather be thought of as stimulating further creative fields of engagement, posing further questions and potential creative applications. When speaking of the process of creating new instruments Jordà writes:

> designers do not have to limit themselves to [the instrument's] sonic capabilities (which can be absolutely any), not even to their algorithmic power; they must be also especially careful about the instruments' conceptual capabilities, to the ways instruments impose or suggest to their players new ways of thinking, new ways of establishing relations, new ways of interacting, new ways of organizing time and textures; new ways, in short, of playing new musics (2004:1).

Similarly, the outcomes of this project for my artistic practice are stimulating new ways of thinking about the cyber-guitar, new relationships with the instrument (both standard and augmented), new concepts of time and texture expressed through both improvisation and composition, and possibly new musics as yet unrealised. As this project comes to a close I

find myself still in the processes of refinement and creation, of imagining new ways of working with and expanding the system.

Included on the accompanying DVD in Appendix D is a recording of the concert titled *3 Cities* featuring the cyber-guitar along with collaborators Lukas Ligeti and Jonno Sweetman on drums which took place in April 2015, a year after the *Hymnus* concert. By this time, and as the user of the cyber-guitar, I felt I had a greater degree of personal familiarity with the system, exhibiting an ease of access to and mastery of the nuances available through the system during the performance, both in rehearsed materials and in improvisations. In fact, I found the experience of using the system during this concert approaching my experience of playing the classical guitar, where the musical choices were immediate and nuanced without inhibition. I also found that the complexities of the cyber-guitar system were holistically integrated into my playing, fused with my previous capacities and stylistic tendencies as a guitarist, posing significantly fewer constraints on my improvisational desires.[56] This integration was felt throughout the system; in the loop configuration, the exoskeleton and on the effects enabled guitar as well. Whilst the effects located on the guitar didn't impact my existing guitar technique (as neither did the exoskeleton) I felt that by this performance their use flowed more fully and freely.

The *3 Cities* concert featured a number of compositions by the iconic grunge band Nirvana along with the theme from section seven of *Hymnus*.[57] The fourth track on the recording is a rendition of the composition *Expressions of a Neurotic Impulse* by Vietnamese trumpeter Cuong Vu and I propose that the performance of this composition displays aspects of my musical practice that existed prior to the commencement of this research project, such as the linear nature of improvisation, alongside elements emerging out of it, for example the allowance for the radical effects to shape the improvisation.[58] The *3 Cities* concert displayed

[56] For the *3 Cities* concert I added to the system further. I had access to a Korg Kaoss pad that has a touch sensitive pad for selected effects modification. The exoskeleton is not, yet, attached to the lower body and I was able to add new effects changes by playing the Kaoss pad with my feet.

[57] We improvised over three compositions by Nirvana, *Heart Shaped Box, Lithium,* and *Smells Like Teen Spirit. Heart Shaped Box* and *Lithium* were composed exclusively by Kurt Cobain whilst *Smells Like Teen Spirit* was composed by Kurt Cobain, Krist Novoselic, and Dave Grohl.

[58] *Expressions of a Neurotic Impulse* is a composition from Cuong Vu's 2005 album *It's Mostly Residual* featuring Stomu Takeishi on bass, Ted Poor on drums, Cuong Vu on trumpet, and Bill Frisell on guitar.

an integration of the system in an organic way fusing what had come before with what has emerged out of the research. The track begins with a fairly un-effected exposition of Vu's theme until 1:36 and, thereafter, sonic aspects of the system are engaged during the improvisation. From this point until approximately four minutes into the performance Ligeti and Sweetman trade ideas with the cyber-guitar, with looped materials and random pitches shaping their responses. The multi-layered sonic textures from the system shaped the improvisation whilst allowing for spontaneous unison-type events that were not cued, moments where all three performers played loud short fragments of material together interspersed by periods of loop playback. From 4:00 to 6:10 the improvisation unfolds in a jazz-influenced free improvisatory manner. This direction was set upon due to Sweetman interpreting the random pitches generated by the cyber-guitar's ring modulator in a swing style, with the rest of the group then exploring the idea further. The improvisational exploration continued until 6:50 after which the pitch components of the suit began to shape the improvisation more aggressively. During the early portion of this aggressive sounding section the improvisation retained aspects of jazz phrasing (in terms of rhythmic subdivision and phrase contour). However as the section progressed the aggressive quality in the pitch variation from the cyber-guitar caused the ensemble to abandon the jazz reference.

The objective of this research project was not to invent a completely new instrument, but to extend the capacities of the guitar within my practice through notational, sonic and technological exploration and augmentation. The compositional and performance outcomes of the notational interrogations have not arrived at a singular 'best case' scenario. The rehearsals and performances with different types of notated musics, however, have revealed that there is an interrelationship between notational practices and the resulting output of any individual or group performance where musicians have previously been involved with or refused notation; that is, the outcome is determined by more than just the use of or rejection of a score. (This is in contrast to Cardew's speculation that the visual forms of *Treatise* would allow musicians to realise more freely a spontaneous creation.) In the concerts presented as part of and during this research project I observed that the presence or absence of notation in a concert performance, or during the preparation for a performance, significantly impacts the outcomes in a way that is intrinsically linked to the use, rejection or agency of notation within the musical histories of the performers involved. The perspectives of the musicians involved are present regardless of the use of notation in a specific performance circumstance. Put

simply, performers bring their perspectives on and opinions about notation (and other matters) into the performance and these affect the outputs.[59]

For example, in *Expression of a Neurotic Impulse* from the *3 Cities* concert no score was supplied to the percussionists, and they were not familiar with the composition prior to rehearsal on the day. At rehearsal I played the head structure for the drummers a number of times the nature of which shaped the energy, duration and unfolding of the work in performance. It was recognisably located within the modern jazz tradition taking the structure of a head followed by improvisation. The linear expressions of the improvised section as well as the duration of exploration were congruent with practices common to the type of modern jazz from which the work stemmed. Thus while the cyber-guitar system exhibits a plasticity that can accommodate the impact of different types of notational practice on performance, the presence or absence of notation bear on the outcomes of the performance. At the outset of this research I had imagined that the instrument and notation would be interlinked in a more constrained manner and that the sonic outcomes would reflect that. Rather what has been revealed is that notation has a pervasive influence on performance and is not tied to the instrument's design.

The boundary between noise and music was another core area explored in the research, allowing creative interrogations, in the concert performances, which moved into uncharted territories within my practice. I sought to understand the concept of noise within this research project not in relation to directing the musical outputs towards existing noise music practices, but in terms of understanding the location of noise within the creative paradigms of the system. Noise here functioned not as a binary opposite to music, but rather by positioning the capacities for sonic output of the system (and the notational paradigms that facilitated this) in ways that propelled the user/s into unexplored territories noise could create new creative motivations, as in Shannon's theorem, and new forms of knowledge. Noise was conceptualised as a constructive impulse, rather than an impulse that was considered in opposition to standard definitions of sound. The design of the system sought to be 'noisy' not

[59] Even in a case where notation was not present, such as in the concert staged as part of this project, *What if the machines took control*, the musicians involved approached the concert performances in ways that were influenced by the agency of notation in their creative practice. The concert had no structure (beyond time limitations) or score, yet the reflections of the musicians interviewed revealed expectations that are linked to their own aesthetic positions on notation.

only in its sonic output sometimes, but in ways that would stimulate musical invention towards ends that I would otherwise not have been drawn to.

As mentioned earlier the design and building of the cyber-guitar was not approached with an intent to critique the existing design of a guitar or to completely rethink the configuration or function of musical instruments. The approach to technological ascendance or organological innovation was one that was directed by my desires of musical creation. Through attempting to understand the nature of instruments historically and locating this knowledge in my own musical history with the guitar I sought to interrogate the ways that an expanded instrument may facilitate new types of practice. These new practices should allow the user of the augmented instrument to capitalise on their lifelong performance skills investment while holistically expanding the capabilities of an instrumentalist's future work.

In the analysis of instrumental design covered in chapter three I noted that deviation from a standardised instrument design was not always enthusiastically explored during a portion of the twentieth century by musicians and instrument makers. The reluctance to accept deviations in design was multifaceted, informed by economic, individual and compositional constraints. These constraints manifested not only in the stagnation of instrumental design in the past but can also be seen in the radical nature of new instrument designs during recent years: an exploration of designs unlinked to instruments of the past. This research project proposes that the intersections between, rather than refuting of, the past and present conceptions of notation, noise and instrumental design present an alternative way forward in the design of new musical interfaces and augmented instruments; and further that perhaps the longevity of any technological innovation in instrumental design is intrinsically linked to existing design and performance practice on an instrument, such that developments should therefore seek to marry the two.

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Appendix A: What if the machines spoke back to you?

1) What if the machines spoke back to you? August 2011.

    Jonathan Crossley- Cyber-guitar
    Jacob Israel – Electronics
    Justin Badenhorst – Drums

Recorded and mixed by Jonathan Crossley

Appendix B: What if the machines took in control?

2) What if the machines took control? September 2012.

Jonathan Crossley- Cyber-guitar
Jacob Israel – Electronics
Justin Badenhorst – Drums
Carlo Mombelli – Bass
Joao Orecchia – Guitars and electronics

The audio for this recording was taken from a camera microphone and is not a studio recording. It is included for reference purposes.

Appendix C: The Cyber-guitar Recital, *Hymnus.*

3) The Cyber-guitar Recital, *Hymnus*, March 2014.
   Jonathan Crossley- Cyber-guitar
   Jonno Sweetman – Drums
   Justin Badenhorst – Drums
   Carlo Mombelli – Bass

Video direction by Eran Tahor
Live Engineering and Recording by Larry Pullen
Mixed by Jonathan Crossley

Appendix D: 3 Cities, Crossley, Ligeti and Sweetman in Concert.

4) 3 Cities, Crossley, Ligeti and Sweetman in Concert, April 2015.

Jonathan Crossley- Cyber-guitar
Lukas Ligeti – Drums
Jonno Sweetman – Drums

Recorded and mixed by Jonathan Crossley