CERTIFICATE OF ORIGINAL AUTHORSHIP

I, Alexander White, declare that this thesis is submitted in fulfilment of the requirements for the award of Doctor of Philosophy in the Faculty of Arts and Social Science, School of Communications, at the University of Technology Sydney.

This thesis is wholly my own work unless otherwise referenced or acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

This document has not been submitted for qualifications at any other academic institution.

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Resurgence: Experiences and Impacts of the Contemporary Modular Synthesiser

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Format of Thesis

The research was undertaken as a conventional thesis.

Contents

List of Figures

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List of Publications

The following publications were produced during the research project and drew upon the research process.

White, A. (2019). *Analog Algorithms: Generative Composition in Modular Synthesis*. Australian Computer Music Association 2019, Melbourne, Australia.

White, A. (2022). Unstable Structure: The improvising modular synthesiser. *Organised Sound*, 1–11. https://doi.org/10.1017/S1355771821000595

Abstract

The contemporary re-emergence of the modular synthesiser as a popular tool for music making sits in contrast to much of the development and design of other electronic music-making equipment over the past forty years. The modular synthesiser user eschews, the convenience and recallability enabled by digital and computer-based instruments and tools, thus challenging understandings of the relationship between electronic music composers and technology.

This research project explores how modular synthesisers are used, what is valued by musicians and composers in their experiences of working with modular synthesisers, and how modular synthesisers enable these experiences. Driven by an interpretive, phenomenological perspective, I interviewed musicians who use modular synthesisers to capture their interpretations, experiences, values, and drivers behind the use of these instruments in music composition. With creative practice as a research tool, I adopted a reflective process to generate and test concepts, build understanding and empathy with other practitioners, and describe their first-hand experiences of using modular synthesisers.

Four themes emerged from the research:

Instrumentalising the studio refers to the use of a modular synthesiser to incorporate any components or processes of a contemporary electronic music studio into the form of an instrument, that exhibits a level of permanence and physicality enabling it to be learnt, performed, and improvised upon.

Modular synthesisers as compositional tools acknowledges the possibilities for modular synthesisers to generate, organise, and structure musical events at a range of time scales, contrasting this in relation to fixed architecture synthesisers. Modular synthesisers exhibit a range of attributes when used to create musical structure, including real-time manipulation and improvisation of musical structure, and systematisation leading to the potential for chaos and complexity to emerge.

Discovery and co-creation refers to the use of a modular synthesiser as a deliberate strategy to experience a sense of discovery, as sounds and structures emerge that are desired but not planned or preconceived. To achieve this the musician gives over a level of agency to the instrument so that they and the machine are in a process of co-creation.

A range of legacies and diversions from the historic origins of modular synthesisers are identified under the theme of *the contemporary modular synthesiser*. The original intention to

enable the possibilities of the tape music studio to be performed and improvised remains, but the inclusion of digital modules and the plethora of manufacturers producing modules for the Eurorack format significantly impacts experiences of contemporary modular synthesisers.

Introduction

Originating in the 1960s, modular synthesisers were the first widely available commercial synthesisers, their appearance heralding a new era of electronic music beyond the avant-garde (Bode, 1961). In the early 1970s, keyboard-based, fixed architecture synthesisers such as the Minimoog and ARP Odyssey were introduced, proving to be highly successful due to their simplified structure, portability, and lower cost compared to their larger modular forebears (Pinch & Trocco, 2004). While a few small companies continued to produce modular instruments and components well into the 1980s (Vail, 2000), modular synthesisers essentially became a historic oddity, used and valued by only a small population of enthusiasts.

Over the past decade, modular synthesisers have re-emerged as a popular tool for electronic music composition (Roads, 2015). The Eurorack modular standard, established by Dieter Doepfer in 1995 (Dalgleish, 2014), has emerged at the forefront of this resurgence. As of December 2022, there were more than 500 Eurorack module manufacturers and more than 10,000 modules listed on the ModularGrid website database. Although a number of entries only reference alternative panel designs or minor revisions, these numbers indicate both an active scene and a significant component of the electronic music instrument market. The legacy of historic modular synthesiser design is apparent within this newly emerged market through the licensed manufacturing of older designs, and also in the contemporary designs that build upon or reference specific models or concepts.

The commercial opportunity of the modular synthesiser market has compelled many of the larger established instrument companies to offer compatible products or modules. These companies include Moog, Arturia, Behringer, Dave Smith Instruments, Waldorf, and Elektron. The effects of the modular synthesiser resurgence are also apparent in software-based tools, with companies such as Native Instruments, Cycling ’74, and Madrona Labs now offering software that emulates the modular synthesiser paradigm, and even offering the potential for compatibility with hardware-based modular synthesisers.

The shift to modular synthesisers was neither driven, nor predicted, by these larger electronic musical instrument companies. Given the investment in research and development of commercial electronic instruments and musical interfaces since the early 1970s, it is unusual that such an old paradigm would again find relevance and become a significant segment of the market for electronic music equipment.

A Practice-Led Inquiry

I have worked with modular synthesisers since 2011, and my experiences with them have contributed to substantial shifts in how I approach music making and performance. Given the two-decade dominance in music making since the late 1990s of the ubiquitous computer, with its endless updating of software and hardware, there is a temptation to situate the modular synthesiser in counterpoint, focusing on its tangible interface as a primary driver for the return to modular synthesis (Paradiso, 2017). This desire formed some of the initial impetus for my exploration of modular synthesisers in my creative practice. However, my ongoing interest has also been stimulated by the specific generative possibilities and compositional frameworks I have found to be embedded in individual module designs, and in the modular paradigm itself. I have undertaken this research in order to describe my own and other musicians' experiences so that a detailed understanding of the phenomenon, grounded in the experiences of creative practitioners, can be offered.

Research Question

This research project undertakes to examine and describe how modular synthesisers are used, determine how the experience impacts upon the processes of music making, and show why the experience is valued by musicians.

My enquiry is descriptive in nature, and I have not attempted a comparative determination of what aspects of the experience are more dominant among users, nor what the most popular approaches are to using a modular synthesiser. Similarly, I have not attempted to investigate why, or how, the resurgence of modular synthesisers has occurred. A thorough study of the cause of the phenomenon would likely draw on a range of technological, economic, and cultural factors alongside an analysis of musicians' experiences. The thematic descriptions presented here may inform the development of future research instruments designed to measure the various drivers of the phenomenon.

Knowledge Gap

To date, no other scholarly research has sought to understand the resurgence of the modular synthesiser. Anecdotal media sources have mentioned potential drivers for the phenomenon, such as musicians seeking to access an authentic analogue sound, or nostalgia for older instruments and processes (Ableton, 2015; Modular Synth, 2020; Meindl, 2019). With this investigation into the re-emergence of what was previously considered to be an obsolete technological paradigm, I have sought to learn what it is that musicians value from their experiences of using these instruments and thereby contribute to the knowledge of electronic music practice.

Significance

In comparison to many other contemporary digital and software-based music technologies, the modular synthesiser lacks a range of conveniences such as state recall, speed of process, accuracy, polyphony, and portability, yet it is becoming increasingly valued by musicians. I hope that this study's findings will assist in the design of future instruments, both modular and fixed architecture, and even software. This resurgence also raises a broader question about our relationship with technology in creative settings: In our use of technology, what do we seek, appreciate, and avoid?

Research Methods

The research was undertaken as a phenomenological inquiry (Schütz, 1967), because this approach foregrounds the subject's own interpretation of an experience in developing thematic descriptions of the phenomenon of interest. The interview design and analysis were guided by Moustakas's (1994) work on translating a phenomenological approach into practical research processes. This was augmented with the design research technique, Contextual Inquiry (Holtzblatt & Beyer, 2016), which situates the subject in the environment being investigated, so that the data-gathering process can draw upon the subject's interactions, gestures, and processes *in situ.* To assist in the interpretation and analysis of data gained through the interviews, I applied a reflective practice approach (Schön, 1983) to my own creative practice processes and outcomes. These outcomes include recordings, releases, and public performances, as a component of the research instrument. The creative

practice research is described in Chapter 4. Twenty-one practitioners were interviewed in a semi-structured style, both in person and remotely due to the impacts of COVID-19 upon travel and social distancing. This data was analysed and then organised thematically and is presented in Chapter 5.

Structure of the Dissertation

In addition to this introduction, the dissertation is organised into the following seven chapters.

Chapter 1. Background

Drawing on the literature, I describe the development of the first modular synthesisers, the commercial shift to fixed-state instruments, and the contemporary resurgence of modular synthesisers. The term *composition* is discussed in the context of contemporary electronic music to provide a basis for how composition is understood in this research. The chapter concludes by identifying gaps in current knowledge relevant to an understanding of the experience of using contemporary modular synthesisers.

Chapter 2. Methodology

This chapter defines the scope of the research, describes the positionality of myself as a researcher, and explains the phenomenological approach used.

Chapter 3. Research Design

In this chapter, I describe the methods and processes used in the project to collect and analyse data, and identify potential ethical concerns.

Chapter 4. Creative Practice

This chapter recounts my creative practice and its contribution to my research. In it I set out my insights into my creative practice and discuss how making explicit my experiences and interpretations enhances the depth and integrity of the research.

Chapter 5. Analysis of Practitioner Interview Data

To illustrate key findings in the context of each participant's practice, this chapter presents thematic descriptions of the data gathered through analyses of practitioner interviews, accompanied by direct quotes and more detailed vignettes or case study descriptions drawn from the interviews.

Chapter 6. Discussion

This chapter discusses and organises the thematic findings into broader concepts, making the case for a range of ideas more broadly relevant to electronic music practice, instrument design, and human creativity in conjunction with technology.

Conclusion

This chapter summarises the project's key findings and suggests potential future inquiries into modular synthesisers, electronic music, and human creativity.

Chapter 1. Background

Historical Context

The modular synthesiser has been described from a range of distinct contexts as a new instrument, a historic instrument, and more recently, as an instrument reborn. This research project is operating from the last perspective. The significance of the inquiry is reliant upon this seemingly obsolete technology finding broad utility and cultural relevance in a contemporary context. In examining the literature related to the research question, I have encountered perspectives ranging from the original emergence of modular synthesisers in the 1960s through to their contemporary re-emergence over the past decade, including the considerations of instrument designers and musicians.

There is a tendency for historical overviews relating to the development of electronic instruments in the twentieth century to discuss instruments introduced prior to the development of the first commercial synthesisers. Instruments such as the Telharmonium, Theremin, Ondes Martenot, Melochord, and Electronic Sackbut are all fascinating designs of historic importance in the broader history of electronic music and well recognised in a range of texts (Holmes, 2015; Manning, 2013). Given that the focus of this research inquiry is commercially available instruments developed at the time of the emergence of modular synthesisers, other historic instruments predating the commercial introduction of modular synthesisers have only been included where an influence or connection could be established through the literature or primary sources. It would also be out of scope to offer a comprehensive historical narrative of all modular synthesisers ever constructed. Such an undertaking would be fascinating, but also time consuming and unnecessary to the stated intention of this research.

Connections to Tape Practice and Improvisation

The musical instrument designer Harald Bode is generally credited with the invention of the modular synthesiser, as documented in his article published in the trade journal *Electronics* (Bode, 1961), where he described a “synthesiser” apparatus that used voltage control to connect distinct components. He described his synthesiser as offering “immediate processing” of sounds and situated this in contrast to “intermediate” processes where “the composer-performer cannot immediately hear or judge his performance, therefore corrections can be made only after some lapse of time” (p. 2). Bode cites the use of punch

tape, most likely a reference to the RCA Synthesisers (Manning 2013 pp.81-97), and magnetic tape composition as examples of “intermediate process”.

Bode’s synthesiser design incorporated a tape loop device with a record head and three playback heads (Bode, 1961). Throughout the article he described the potential uses of the instrument and repeatedly situated the tape loop device as a core component. This integration of a tape loop into the device and its intended functionality sits awkwardly with common understandings of a synthesiser as a generator of signals and conceptually separate to recording devices, but this confluence is not exclusive to Bode.

Electronic music in the post-World War II era was almost inseparable from tape recording technology (Chadabe, 1997; Holmes, 2015; Manning, 2013). The majority of electronic music produced between 1948 and the advent of synthesisers in the early 1960s was created using the “classical” tape-based techniques of tape splicing to create a sound montage (Powers, 1997). As already identified by Bode, these processes did not occur in real time, instead taking weeks or months to complete works of a significant length. During these years, interest in improvisation as an approach to composition and performance of electronic music was also building (Holmes, 2015); however, classical tape processes do not easily lend themselves to real-time performance and improvisation.

In 1961, Pauline Oliveros, Terry Riley, and Ramon Sender organised the Sonics series of concerts in San Francisco. Later joined by Morton Subotnick, the concerts featured presentations of tape works alongside improvised group performances (Bernstein, 2008). After forming the San Francisco Tape Music Center, the members' key interests in tape-based music practices and improvised performances generated a contradiction they sought to resolve. Deeply interested in improvisation and the role of listening in performance, Oliveros developed a range of techniques that allowed her to create tape music in real time and to hear the results in real time (Gordon, 2018; Holmes, 2015; Powers, 1997). Similar motivations led to the engagement of Donald Buchla by Sender and Subotnick to develop a new electronic instrument (Bernstein, 2008).

Envisaged as a means to reduce the labour involved in splicing tape (Bernstein, 2008; Chadabe, 1997; Pinch & Trocco, 2004), the Buchla 100 series Modular Electronic Music System, delivered in 1964 (Bernstein, 2008), came well equipped to generate musical events, with three separate sequencing modules, each with as many as 16 steps (Howe, 1967). Morton Subotnick has described the compositional techniques used with the Buchla 100, which enabled complex rhythms to be generated over long periods by combining the

various sequencers at odd and differing lengths, or by applying voltage from other sources such as envelope generators to adjust the timing of a pulse generator (Vail, 2000).

The relationship of the Buchla 100 to tape practice extends beyond a conceptual instigation to the technical and practical. As Subotnick revealed:

> *The ten-note keyboard [Don made earlier] everybody thought was because we have ten fingers, but it was because we had ten Viking loop decks. The finger pressure was in order to be able to do musique concrete and to control the amplitude on the Viking loop machines.* (quoted in Bernstein, 2008, p. 166)

Similar to Bode's 1961 instrument, the Buchla 100 incorporated a level of integration with tape, providing amplitude control through the Buchla's mixer (Gordon, 2018). Subotnick later developed a technique that inverted this relationship, enabling tape machines to control the Buchla's parameters, and used recordings of his voice processed through envelope followers to produce control voltage signals (Hanson, 2010). This process enabled Subotnick to enact expressive control through the energy of his voice, and to create the possibility of precise control of parameters, perhaps ironically through tape splicing techniques.

Robert Moog's development of the Moog synthesiser simultaneously with Buchla's instrument is similarly linked to tape practice through Moog's association with the composer Herb Deutsch, an encounter that initiated the process of designing and prototyping what was to become the Moog synthesiser (Pinch, 2006; Pinch & Trocco, 2004). Akin to the desires of Sender, Subotnick, and Oliveros, Deutsch was also seeking a more dynamic and direct relationship with electronic music making than the classical tape studio techniques allowed. While the developmental path of the Moog eventually took various turns towards traditional instrumentality, composers still used Moog components to manipulate tape, as evidenced by Vladimir Ussachevsky's employment of a custom-built Moog envelope to enable amplitude contouring of recorded sounds (Pinch, 2006).

Given the ubiquitous and central role of tape practice for electronic music in the period leading up to the development of synthesisers, this close integration of tape and early synthesisers is hardly surprising. However, this aspect of electronic music history implies the earliest intentions for the role of a synthesiser were more akin to those of the contemporary Digital Audio Workstation (DAW), or sampler sequencer combinations such as an Akai MPC 2000 or an Elektron Octatrack, than to a traditional instrument such as the organ or piano.

Indeterminacy and Imprecision

> *There are also people like Morton Subotnick and Suzanne Ciani who are concerned, as Cage was, with production of music as a process, where to realise your music, you would organise a very complex system. The Buchla modular system was designed with this sort of composer in mind more than ours was. It has a lot of capability for triggering sources in sequence, for turning on and off different sources, and for creating a very complex organisation of a modular system. You can literally set up a machine that will produce an interesting sounding piece of music by itself.* (Robert Moog, quoted in Hutchins, 1974, p. 48)

As with improvisation, indeterminate approaches to composition raised potential issues for classical tape-based processes. Composers involved in the San Francisco Tape Music Center experimented with various methods of indeterminism in both composition and performance (Bernstein, 2008) and presented performances and works by both John Cage and David Tudor (Pinch & Trocco, 2004). Cage's desire to decouple performance from composition through chance operations was largely incompatible with tape music as a final output due to its fixed and linear format (Holmes, 2015).

The Buchla 100 was well equipped to incorporate indeterminate processes with its inclusion of the Model 165 Dual Random Voltage Source (Hernandez, 2017; Powers, 1997), which was essentially a pair of sample and hold circuits, each combined with a noise source. Donald Buchla developed these concepts further in 1969 with the Model 265 Source of Uncertainty (Pinch & Trocco, 2004) and later with the Model 266 by incorporating shift register-style circuits and offering a range of randomised and slewed voltages outputs (Hernandez, 2017). These modules enabled any parameter of the Buchla to be randomised, thus allowing for compositional systems to be created that would never repeat themselves. Composer Pril Smiley described her experiences of working with this aspect of the Buchla:

> *I spent a lot of time and energy trying to get synthesisers to be more irregular. … I did not want to splice a whole piece with every note having a different time value, the way it really is when a performer does it. ... We just would try to program irregularity into a given sequence of anything. … That's something you can obviously do with the voltage control aspect, and I found it a wonderful advantage, so that another row of knobs would be dedicated to volume that would end up sounding like different accents, or different volume values for each note in a sequence. To make each individual note a little different than the last one, and get them sequenced. And the Buchla lent itself to that.* (Smiley, quoted in Powers, 1997)

For the Buchla, indeterminacy forms a design driver that is drawn from a deliberate compositional philosophy that is firmly embedded in the avant-garde. With chance operations situated within the device itself, the Buchla enables composition and performance to be simultaneously deliberate and decoupled, further blurring the functionality of the Buchla device as a compositional and performative instrument.

Borrowed from Analogue Computing

> *The modern approach of synthesising intricate electronic systems from modules with a limited number of basic functions has proven successful in the computer field, This approach has now been made in the area of sound synthesis.* (Bode, 1961, p. 5)

Bode attributes the modular approach utilised in his 1961 synthesiser design as borrowed from general-purpose electronic analogue computing, a form of computing more accessible and prolific in the 1960s than the enormous mainframe precursors to the digital personal computer (Fig. 1) (Small, 2001). Largely driven by aerospace and military applications, electronic analogue computers enabled real-time simulation of mathematical systems and physical phenomena. An examination of the typical components of an analogue computer reveals physical design similarities to modular synthesisers, including patch points and standardised module formats.

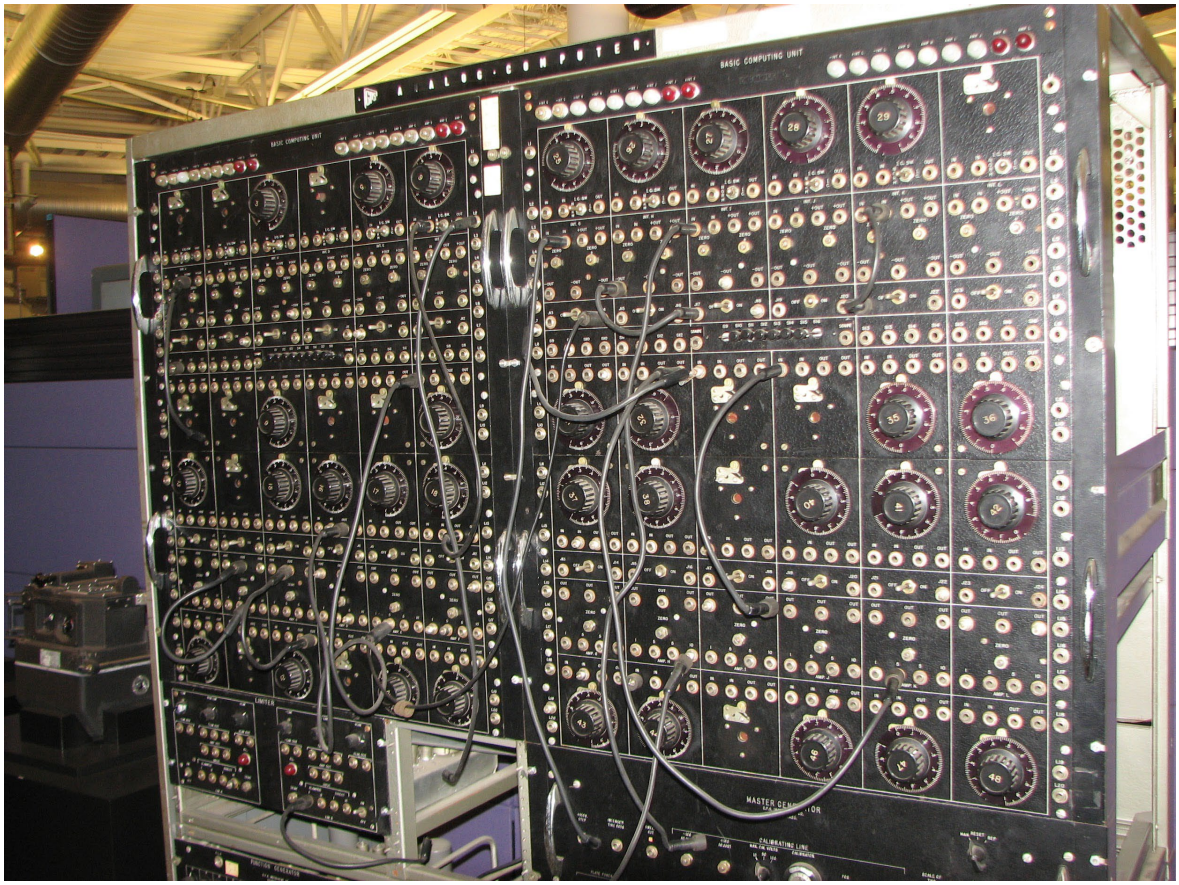


Figure 1. GPS Analogue Computer Source. Photo Erik Pitti, 2008. Used under CC license.

The similarities between the two technologies extend further than their interfaces or even the reconfigurable modular paradigm. The functionalities of the components themselves are essentially mirrored, such as mixers (summing), voltage-controlled amplifiers (multiplication), envelopes (function generators), logic gates, inverters, and comparators, among others (Dalgleish, 2016; Dalgleish et al., 2015; Gordon, 2018; Roads, 2015; Teboul, 2017). This connection to electronic analogue computers brings with it implications for the algorithmic and generative aspects of modular synthesisers and situates them as compositional systems, as opposed to more traditional understandings of an instrument as a device that is only performed upon.

Stabilisation and Demise

In the early stages of the development of the Buchla and Moog instruments, their potential uses were largely undefined. As identified above, major design considerations such as generation of electronic sound signals or manipulation of tape were drawn from the desire to speed up tape composition processes and to enable a more direct relationship between the musician and the possibilities of electronic music. Buchla instruments are also reported to have functioned as controllers of lighting and projection systems (Gordon, 2018), including at

the Trips Festival in 1966 (Bernstein, 2008) and the Electric Circus Club in New York (Gluck, 2009), and to have performed various other less-defined functions in contexts such as Ken Kesey's bus “Further II”, or in service to the Hells Angels (Gordon, 2018).

Buchla was focussed upon the device being an instrument (Teboul, 2017), but in his view the possibilities for electronic music were broad and unlimited. He resisted providing a keyboard interface where pitch would be limited to 12 tones (Bernstein, 2008; Pinch & Trocco, 2004). Sender advocated for a keyboard to be embedded in the design of the first Buchla, but Subotnick sided with Buchla, and Sender was overruled (Bernstein, 2008).

Moog was also faced with differing views on the inclusion of a keyboard. Deutsch, who had initiated the design process, insisted upon the keyboard as the primary interface, but Vladimir Ussachevsky urged Moog to abandon it (Dalgleish, 2016; Pinch & Trocco, 2004). However, Wendy Carlos encouraged Moog to develop the keyboard further, resulting in the first touch-sensitive keyboard (Pinch & Trocco, 2004), which Carlos then used to produce the album *Switched on Bach* in 1968. Carlos’s record brought the Moog synthesiser and electronic music more generally into public awareness and cemented the association of the keyboard as the interface of synthesisers.

In 1970, sales of Moog’s modular synthesiser dropped off sharply (Vail, 2000), but Moog had released a new instrument design in 1969 that was building momentum, the Minimoog D, which would eventually be sold in the tens of thousands (Holmes, 2015). The Minimoog D had several commercial advantages over the larger modular instruments because it had a fixed architecture design with standardised connections between components, greatly simplifying its design. One advantage was its integrated keyboard interface, which made its use more apparent to potential users (Paradiso, 2017), particularly as a performance instrument. Its size allowed it to be portable and its cost made it more accessible. The success of the Minimoog encouraged other companies to develop similar fixed architecture, keyboard-based instruments such as the ARP Odyssey (Pinch & Trocco, 2004). These new, compact devices surrendered much of the flexibility of the preceding modular designs (Holmes, 2015) and firmly established the keyboard as the standard interface for synthesisers (Pinch & Trocco, 2004).

In the 1970s, developments in electronic instrument design such as polyphony, sampling, and timbre presets further alienated the modular design paradigm (Scott, 2016). By the 1980s, with the advent of digital synthesisers, modular synthesisers were considered obsolete (Dalgleish, 2016; Scott, 2016).

Resurgence and Analysis

The past decade has seen a substantial growth of interest in modular synthesisers and an influx of new manufacturers, designers, and modules (Chambers, 2019; Dalgleish, 2016; Dalgleish et al., 2015; Haddad & Paradiso, 2019; Hernandez, 2017; Magnusson, 2019; Paradiso, 2017; Roads, 2015; Rossmy & Wiethoff, 2019; Scott, 2016). The Eurorack modular standard established by Dieter Doepfer in 1995 (Dalgleish, 2016) has emerged at the forefront of this resurgence. As Scott (2016) commented:

> *I have pointed out that nobody could have predicted the scale of the return of such an inconvenient, time consuming, bulky, expensive and inefficient tool as the analogue modular synthesizer. I can't quite think of another precedent for the reinstatement of a whole genre of instrument thought to be obsolete in a music tech industry that generally seemed to have its eyes fixed on the future, on technological progress and on the next smaller and more convenient product about to be launched.*

This resurgence of modular synthesisers was not predicted by industry or academia. Large electronic music manufacturers such as Korg, Roland, and Moog have slowly responded but have not contributed to the resurgence (Scott, 2016). This occurrence in the context of flexible and powerful digital music technology raises fundamental questions about the relationship between artists and creative technology (Dalgleish et al., 2015; Haddad & Paradiso, 2019; Scott, 2016).

Drivers

Researchers have sought to understand modular synthesisers in the context of contemporary electronic music practice and what might be driving their resurgence; in popular culture, it is often attributed to musicians' interest in "analogue" sound (Scott, 2016). Scott (2016) cites the widespread use of digital sound sources and processes within and alongside modular synthesisers and argues that the attribution to "that analogue sound" may be an easy way to avoid a more complex inquiry. Many module designs do emulate specific fixed architecture analogue synthesiser circuits, and it seems possible that for many musicians a modular synthesiser may simply function in the same way a fixed architecture synthesiser might, but with options such as filters to choose from (Hernandez, 2017).

The proliferation of modular synthesisers on stage, in press shots, and even on television is testimony to the visual spectacle these large, physical, and complex objects offer (Paradiso, 2017). From the audience's point of view the modular offers an inversion of the opaque and inscrutable laptop (Cascone, 2002). The comparison to laptops is difficult to avoid and it seems clear that modular synthesisers offer a more tangible interface (Neal, 2014), a dedicated knob per function, and absence of menu systems (Scott, 2016; Setabundhu & Setabundhu, 2018), although this is not the case with many digital modules.

The interest and search for suitable and innovative interfaces for computer based musical instruments is apparent in the NIME conferences, which since 2001 have proposed a range of approaches to new interfaces for instruments, often utlising software-based sound engines. The NIME movement builds on a tradition of creative research into new musical interfaces formalised in institutions such as STEIM (Wanderley 2023). If the resurgence of interest in modular synthesisers is partially driven by a dissatisfaction with the seemingly ubiquitous laptop as a musical instrument for performance, then a similar driver is likely to be present in the NIME community’s parallel activities in seeking new interfaces, and framing these as musical instruments. A survey of NIME innovations (NIMEconference, n.d.) indicates that “musical expression” in this field extends beyond the development of performance interfaces to an interest in new ways of controlling compositional processes (D'Arcangelo. 2001) and this also parallels aspects of the resurgence of modular instrument explored below and expanded in Chapter 6.

In a further comparison to computer-based music making, a modular synthesiser can be generalised as being more limited in its components – assuming the modular synthesiser does not fill an entire house – and therefore easier to learn (Neal, 2014). The nature of voltage control has been described as offering a higher resolution in comparison to digital-based audio systems (Setabundhu & Setabundhu, 2018). A factor that I can personally attest to is that modules do not become obsolete, thus enabling musicians to avoid the constant expense and inconvenience of software upgrades (Paradiso, 2017). The stable resale value of modules is another advantage in comparison to software.

The sheer physicality of modular synthesisers has a range of impacts, including engaging spatial memory (Paradiso, 2017), engaging the body through literal interfaces that evoke gesture (O Connor, 2019), and operating as a musical instrument (Scott, 2016). Scholars have asserted that the physical interface offers an engaging and intuitive environment for the musician (Neal, 2014; O Connor, 2019; Paradiso, 2017; Setabundhu & Setabundhu, 2018), even claiming the combination of simultaneously designing an instrument (patch) and creating music enables a highly immersive flow state (Paradiso, 2017, Csikszentmihalyi,

2009). Perhaps operating in concert with this flow state is the inability to save a patch, effectively forcing musicians to create and record immediately, and then compose something different with a new patch (Chambers, 2019; Paradiso, 2017).

Similar to my own observations through reflective practice, others have noted the significance of the designers' own intentions, the conceptions, assumptions and predilections, which become embedded in a module design. The modular synthesiser enables a co-location of these designs in a modular instrument (Paradiso, 2017). Given the open nature of the Eurorack format and the hundreds of manufacturers creating compatible modules, this component of the contemporary experience of modular synthesisers is likely to be unique in comparison to historical experiences of single-manufacturer systems.

Nostalgia for older technologies may also be a possible driver for the resurgence of modular synthesisers (Neal, 2014), with many manufacturers producing designs that draw upon obscure historic instruments such as the Make Noise Phonogene (Make Noise Co. | Phonogene, n.d.), thus connecting modular synthesiser users with histories of electro-acoustic music (O Connor, 2019).

Similar to the maker movement, with which the modular synthesiser communities share many attributes, the internet itself can be seen as a driving factor, as it connects global networks of experts and enthusiasts (Chambers, 2019). This connectivity also fuels another driver, the collecting of modules, which is often described as an addictive or obsessive compulsion. The assumption that the use of a modular synthesiser is inevitably an activity that sits comfortably in a capitalist setting seems reasonable and certainly one that has greatly benefited from the impact of globalisation upon the price of electronics manufacturing and components. However, as with the maker movement, modular synthesiser use has also been posited as an act of resistance to late capitalism through its support of bespoke design, small-scale manufacture, and the creation of individualised unique instruments.

Richard Scott (2016) has also reflected upon the significance of the modular synthesiser resurgence and what its broader implications might include:

> *The second golden age of modular synthesis is perhaps a reflection upon our relationship to technology in general and it is evidence, if any were needed, that as artists and humans we are engaged, that we have choices, and that even microscopically there are still kinds of intervention, choice and control we can exert and decisions we can make about our own personal relationship to the wider technological, political and social forces that shape our lives*. (Scott, 2016)

Other Phenomena

The previous section collected attributions from scholars about what might be driving the resurgence in use of modular synthesisers. There is an overlap between these explanations and descriptions of phenomena experienced in the use of modular synthesisers. The following phenomena were identified in the literature that is not limited to the recent resurgence, and so they may not necessarily contribute to the contemporary increase in modular synthesiser usage.

In 1961, Bode reported on experiments with his new instrument and found that a range of frequencies could be used as control voltage sources, for example, subsonic frequencies, audio-rate white noise, and live inputs such as acoustic drum sources. Bode (1961) labelled this approach “audio-controlled”. Others were also working across a broad spectrum of sound frequencies outside of modular synthesis, such as increasing tempo from rhythmic scale up to an audible waveform, for example, Stockhausen’s use of sped-up recordings of pulses (Nakai, 2016), and Sender’s extreme speed shift of the entirety of Wagner’s Ring Cycle into four bursts of noise (Bernstein, 2008). This broader interest in the use of audio as a sort of flexible material that might operate across a broad range of timescales was encapsulated in the design of modular synthesisers and use of control voltage, something that became apparent to composers as they engaged with modular synthesisers (Paradiso, 2017).

The possibilities for precision, immediacy, and relative efficiency offered by modular synthesisers when they were first introduced in the 1960s was well recognised (Pinch & Trocco, 2004). However, many artists were discovering a sort of wildness and unpredictability residing in the complex flows of energy that could be formed through a patch (Pinch & Trocco, 2004; Powers, 1997). This aspect aligns with explorations in electronic music by Oliveros, Tudor, Cage, and Bebe and Louis Barron outside the modular synthesiser context (Gordon, 2018; Nakai, 2016; Teboul, 2015). Suzanne Ciani summarised her experience of the Buchla: “And it was alive, you know, and you just have it on and you go and you interact and get to know it. You build up a relationship” (quoted in Pinch & Trocco, 2004, p. 163).

The generative and compositional aspects of modular synthesisers have been noted by Blasser (2015), Chambers (2019), Ross (2017), and Setabundhu and Setabundhu (2018). In relation to the processes undertaken by Subotnick using the Buchla 100, where multiple sequencers of varying length were used to produce long and complex music with little repetition, Richard Friedman observed that the composer could discover musical forms

rather than preconceive them (cited in Hanson, 2010). Setabundhu and Setabundhu (2018) describe the interconnected nature of composing with a modular synthesiser: “One can control the temporal related parameters of music in an integrated and organic way, inseparable from the timbre creation aspect. With these additional controls of rhythm, structure, and form, the patch becomes a composition or meta-composition” (p. 2).

Gordon (2018) has reflected on the Buchla operating beyond the scope of what was previously understood to encompass an instrument:

> *Looking for the [Buchla] Box’s differences that made a difference – shows that Buchla’s system created not only new sounds, but perhaps more radically, different dynamics of human-instrument interaction that held the potential to structure new kinds of musicality, beyond understandings of composition and improvisation. Indeed, Buchla’s Box was a diffractive instrument: it did not simply reflect or reposition extant understandings of music, but rather produced new, illegible, and often fleeting events that came to gain meaning (or not) in developing social worlds of institutional electronic music and countercultural exploration.* (p. 78)

The range of timbre made possible by a modular synthesiser is naturally noted but Powers’ (1997) study also uncovered another, less intuitive impact of the shift from classical tape techniques to modular synthesisers: synthesisers actually encourage less timbral change than the rapid chopping and changing of sounds encouraged by hand-edited tape.

Composition in the Electronic Music Context

Central to these enquiries is the concept of composition. Roads (2015) has described nine specific aspects of electronic music composition that expand upon the concept of composition in the acoustic domain. These include the expansion of timbre from defined instruments to the “heterogeneous sound object” (p. 9), the multiscale possibilities for manipulation of structure from the microsound up to an entire composition, the possibilities for timbre and spatialisation to convey musical structure through mutation, and the composer in the electronic studio simultaneously undertaking the roles of composer and performer**.** Over the past 100 years, the re-emergence in Western music of the practices and processes of improvisation have also challenged the traditional Western, acoustic-music understanding of composition by situating the formation of musical structure as a real-time process undertaken by a performer (Lewis, 2002).

Taking these possibilities into account, an understanding of the process of composition must allow for a broad range of activities, from abstracted notation, through to sound-editing processes, and real-time improvisation.

Knowledge Gaps

The resurgence of modular synthesis has clearly opened up new territory for analysing and reflecting on the creative use of technology. While this phenomenon is well noted by scholars, no scholarly work has been undertaken to understand from a user's perspective the drivers, values, or impacts upon electronic music composition associated with the contemporary resurgence of modular synthesisers.

This survey of the background to the resurgence of the modular synthesiser has highlighted origins of the modular in the context of tape composition and improvisation; it has drawn attention to the importance of indeterminacy and imprecision as positive historical values afforded by modular synthesisers; it has foregrounded the potential affordance of algorithmic approaches to composition drawn from the modular's inheritance from analogue computing; it has shown that the force of musical tradition in the form of both keyboard performance and a conventional separation of composition from performance was partly responsible for the demise of the modular; and that the initial liberation from these musical conventions was part of the reason for the original development and adoption of the modular paradigm. This background sets the stage for this research. The relationship in terms of the algorithmic nature of modular synthesisers and role of indeterminacy remain mostly unexplored. Similarly, the shift from tape practice and the interplay of tape and modular synthesiser design in the early years may also reveal how the resurgence is reflecting changing attitudes to composition and performance impacting the role of the synthesiser in contemporary electronic music production.

To address these gaps in our knowledge of the contemporary modular the following chapters examine and describe how modular synthesisers are currently used, determine how the experience impacts upon the processes of music making, and show why the experience is valued by musicians.

Chapter 2. Methodology

Introduction

This chapter presents the methodology chosen to examine and describe how musicians use modular synthesisers in compositional processes. The research was undertaken with the intention of contributing to understandings of the recent re-emergence of modular synthesisers and the broader implications of this phenomenon for music technology, and for intersections of creativity and technology more generally. The impetus for the research was generated through my own experiences of working with a modular synthesiser. However, in order for its outcomes to be generalisable and relevant to other researchers, musicians, composers and instrument designers, the research engages other musicians and composers in an effort to identify common aspects of the experience of working with a modular synthesiser.

The research goal was to establish descriptions and analysis of experiences of using and composing with a modular synthesiser that can contribute to understanding what in the experience of using a modular synthesiser is valued by musicians and how these experiences impact their approach to music-making. While the broader historical context has been examined as background to the study, the contribution of this research relates specifically to understanding the use of the modular synthesiser in contemporary electronic music practices.

To achieve my research goal, the methodology draws upon the sociological qualitative research practice of phenomenology, design inquiry processes, and a process of self reflection as a musician who uses a modular synthesiser.

In recognising that different research approaches yield different outcomes (Tashakkori & Teddlie, 2010), I specifically chose research practices and processes that correlate with my goal of examining and describing, from the musician’s perspective, experiences of using a modular synthesiser.

In this chapter, my overarching research approach – phenomenology – is positioned and elaborated. In Chapter 3 I describe the specific methods or modes of inquiry utilised to achieve my phenomenological intentions.

Positionality in Qualitative Research

Broadly stated, qualitative research is concerned with how the participants in an inquiry interpret their world. Both researchers and research participants, or ‘inquirers’ and ‘the inquired into’, are understood as sense makers, interpreters of their world. In qualitative research, the inquirer and the inquired into are understood to become bound together in the creation of new insights into the phenomenon of interest. The researcher becomes, in effect, the research instrument, with their sense-making proclivities shaping the research. To aid in assessing the trustworthiness and validity of the research it is therefore important that the researcher indicate their underlying sense-making assumptions, together with the social context informing their engagement with the research (Denzin & Lincoln, 2017).

In this section I set out and describe my own social context, perspectives on knowledge, and relationship to the phenomenon under investigation. By doing so I acknowledge that my role as a researcher cannot ever be completely objective. It is intended that the following considerations assist in the interpretation and evaluation of my research.

Ontology and Epistemology

My ontological and epistemological stance accords with what can be described as an interpretivist or constructivist perspective. These perspectives have a rich history in philosophical and social inquiry, and are especially pertinent to approaches that are concerned with making sense of or interpreting phenomena in terms of the meanings people bring to them (Denzin & Lincoln, 2017).

In *Formal and Transcendental Logic* (Husserl, 1977), the German philosopher Edmund Husserl brings attention to the subjective experience of consciousness, and our interpretation of ‘reality’ (ontology). Similarly, my own understanding is that we each have our own subjective experiences and form our own interpretations of these experiences. My research is therefore focussed upon learning, understanding, describing, and analysing the subjective experiences of using modular synthesisers through which the reality of these phenomena are constructed. This understanding situates this research as a form of phenomenological inquiry.

Privilege

As a white, able, straight male residing in a colonised land, I have enjoyed a wealth of privilege and opportunities that have culminated in this research undertaking. Music and technology, as a creative space, have typically marginalised people of colour, women, trans-identifying people, people with a disability and indigenous people (McCartney & Waterman, 2006). Many of the written and mediated histories of electronic music have contributed to this marginalisation (Rodgers, 2010). The field of modular synthesisers can be interpreted as being even further homogenised (Tamirisa, 2014) to a white male space. While this research project cannot resolve these inequalities or selectively interpret histories, there is an opportunity to pay attention to actors and voices that have historically been ignored or de-emphasised. By deliberately engaging with a diverse group of modular synthesiser users, the project is able to contribute knowledge to the contemporary discourse that is broadly relevant and inclusively developed.

Insider

As a participant in the activity being researched, I can be described as an ‘insider researcher’. This may be advantageous to the research process as I am already familiar with the subject and engaged with its associated communities. However, the insider position brings potential disadvantages, including bias towards my own interpretations of phenomena, only focussing upon participants that I already know, and ignoring key aspects with which I am overly familiar (Bonner & Tolhurst, 2002).

The insider/outsider dichotomy itself is problematic, as there are always degrees of belonging (DeLyser, 2001). I have used a modular synthesiser since 2011, I co-directed the *Moduluxxx Festival of Modular Synthesis* in 2012 and 2013 (*Moduluxxx 2012 by Alex White - Pozible*, n.d.), and I have participated in various networks associated with modular synthesis. However, I have not manufactured or designed any modular instruments, I have limited experience in soldering together DIY modules, and my participation in the networked communities has been inconsistent. I also reside in Australia and so am geographically isolated from many of the larger communities in the United States, the UK, and Europe that meet in various face-to-face forums, and so some participants may perceive me as an outsider.

To counter these risks, I have deliberately sought to interview subjects whose approaches and experiences significantly differ from my own, via both purposeful and snowball recruitment. The interpretive phenomenological approach calls for shared understanding to be developed with the interview subjects. This means that the intentions and experiences I interpret and describe will have emerged out of, and be agreed upon by, the interview subjects within the interview process.

Subjectivities

Part of my motivation to undertake this research was to determine if my experiences and interpretations correlate with the experiences and interpretations of other musicians and composers working with modular synthesisers. There is a danger that a research model may be designed to only confirm or emphasise existing pre-conceptions. To counter this, I have utilised open-ended questions designed to elicit descriptions by the interview subjects of their own experiences, thereby limiting the effect of my own presumptions. The inclusion of my creative practice through reflective practice allowed for a formal analysis and description of preconceptions I hold through my own experiences.

Phenomenological Approach

At the heart of this inquiry is an intention to understand and describe the experiences of people who use modular synthesisers. Phenomenological approaches, as explained below, draw upon philosophical orientations and practices, long established in sociological programs of inquiry, to interpret and explain human action and thought through study into the subjective experience of the individual (Holstein & Gubrium, 1994). Over time, phenomenological inquiry has been associated with a range of sociological and humanities related disciplines, such as psychology, education, healthcare, and anthropology (Mwadulo et al., 2020; Denzin & Lincoln, 2017).

The works of Trevor Pinch and Paul Théberge are stand-out examples in sociological analysis in relation to recent histories of music technology (Bijker et al., 2012; Pinch & Trocco, 2004; Théberge, 1997). These approaches have worked with existing cultural artefacts, such as recorded music, published writing, and other media, alongside interviews with key figures, to build narratives that situate both musical instruments and technology in

an expanded social context. My inquiry addresses a contemporary phenomenon. The resurgence of modular synthesisers is arguably relatively recent within the field of electronic music technology and shows little sign of abating. The work of describing and interpreting the experiences of using a modular synthesiser can therefore be undertaken with subjects who are experiencing, participating, and creating in their present-day lives, rather than relying upon recollection of their historic experiences.

The intention of understanding subjective experiences and interpreting them into thematic descriptions that enable broader discussion and analysis aligns well with the phenomenological approach for sociology proposed by Alfred Schütz (Schütz, 1967)**.** Schütz described the intention to understand subjective, lived experiences through description by the subjects and interpretation undertaken in partnership with the subjects (Schütz, 1967).

Phenomenological research approaches have seen broad use in the fields of musicology and ethnomusicology as means of understanding music as a social practice in a range of specific geographic and cultural settings (Berger, 2015). Interestingly, Schütz, a pianist and musicologist, brought his phenomenological approach to inform how music may be understood. His “Fragments on the Phenomenology of Music” (Schütz, 1976) examines the process of experiencing, understanding, and conceptualising music, primarily as a listener. So far there has been scant use of phenomenology in studies of electronic music instruments and tools; see, for example, Fogle’s (Fogle, 2009) phenomenological study into the experiences of the listener to electronic music.

In his seminal text *The Phenomenology of the Social World*, Schütz sought to integrate Max Weber’s conception of interpretive sociology as an endeavour concerned with transformation of subjective experiences into coherent objective descriptions, with Edmund Husserl’s efforts to understand subjective lived experience and meaning making, in order to build a consistent and convincing methodology for the social sciences (Schütz, 1967). Drawing upon Husserl’s unpacking and defining of the subjective processes of experiencing, reflection, meaning making, interpretation, motivation, and actions, Schütz acknowledges that these same processes are undertaken by the researcher who is seeking to understand the subject, and so their own interpretations are also subjective (Schütz, 1967). To circumvent this impasse Schütz builds upon Weber’s concept of the establishment of *ideal types* as the goal of sociological research, where interpretations of multiple subjective experiences build thematic patterns and establish commonalities (Schütz, 1967).

Schütz interprets the concept of the ideal type as a generalisation or abstraction of lived experience:

> *Whenever we come upon any ordering of past experience under interpretive schemes, any act of abstraction, generalization, formalization, or idealization, whatever the object involved, there we shall find this process in which a moment of living experience is lifted out of its setting and then, through a synthesis of recognition, frozen into a hard and fast "ideal type".* (Schütz, 1967, p. 187)

Schütz differentiated between two ideal types. The *personal* ideal type represents a typification or generalisation of a person in a particular situation, or attending to a particular activity (Schütz, 1967). The personal ideal type is similar in function to the concept of a persona in design thinking processes, although the method of deriving it is different (Cooper, 2004)**.** Conversely, the *course-of-action* ideal type refers to specific behaviours, intentions, and interpretations of experience lifted out from the subjective experiences of individuals (Schütz, 1967). Schütz notes that the course-of-action ideal type is directly related to, and formed through, the description of subjective experiences, whereas the personal ideal type can only be derived from, and is reliant upon, course-of-action ideal types, suggesting that the course-of-action ideal type is more closely grounded to the subjective experiences being studied.

The ideal type is not conceived of as universally descriptive of all subjective experiences, nor as representative of a particular experience. It is not thought of as an objective truth, as it is recognised that the researchers own interests and theoretical framework will influence any interpretations that are made. However, despite these limitations, the construct of the ideal type does allow for generalisations to be developed that usefully enable analysis and discourse beyond individual subjective experiences (Johnson, 2008). Phenomenology based research seeks to acknowledge both the complexities of subjective experience, and the complexities of the communication and interpretation of subjective experiences, while still making a case for useful and coherent data to be extracted. The ideal type is the mechanism and form of this data, each lifted out from subjective individual experiences through interpretation and description, all carried out in partnership with the subject.

Schütz argued for the use of phenomenology in understanding music making through the experience of the musician (Shepherd & Devine, 2015, ch. 5). He emphasised a partnership between the researcher and the ‘communicator’ or subject (person ‘inquired into’) as fundamental to building understanding of the experience of the musician. Similarly, other music sociologists such as Peter Martin have noted a need to pay attention to the experiences of “real people in real situations” (Shepherd & Devine, 2015, ch. 9), representing a sort of zooming in to the individual experiences underpinning phenomena. Similar recognition of the insights that phenomenology can provide is also notable in the field

of information and communication technology (Mwadulo et al., 2020). While a very different field from music studies, there is a significant crossover in cases where the technology used to make music is in focus. The argument for a need to understand and learn from the experiences of individuals is valid for both.

Without a depth of insight into the lived experience of people who use a modular synthesiser, any explanation for the re-emergence of these instruments is missing a key component of the puzzle. Driven by a phenomenological perspective, my research method seeks to develop a depth of insight into people's experiences of composing with a modular synthesiser.

A Note regarding Heidegger

The engagement with phenomenology, and the focus upon relationships with modular synthesisers, a form of *equipment*, may give the impression of an obvious resonance with the philosophy of Martin Heidegger (Heidegger & Schmidt, 2010). However, in this research, with my focus on understanding the experiences and interpretations of modular synthesiser users, it is phenomenology as an empirical research approach that is of interest. Edmund Husserl, recognised as the founder of phenomenology, described phenomenology as the study of consciousness, noting that all other sciences rely upon this subjective experience to form logic and knowledge (Husserl, 1977). Both Schütz and Heidegger built upon and critiqued the work of Husserl. Heidegger's work remained philosophical, delving ever deeper to offer definitions, descriptions, and analysis of the human experience of being in the world. Schütz, while also engaged with issues of a philosophical nature, refined an approach that would allow for the study of subjective experiences of phenomena. Given the nature of my research, I am concerned with phenomenology as an approach to receive and understand subjective interpretations of experience and so it is the work of Schütz and through him, Husserl, that I have drawn upon.

Phenomenological Research in Practice

In order to translate and organise a phenomenological research approach into practical research processes I have drawn upon the phenomenological research processes described by Clark Moustakas in his eminently useful *Phenomenological Research Methods* (Moustakas, 1994). Moustakas draws upon a range of phenomenological research projects, including his own, to explain and define processes, and sequences of processes, which

enable a phenomenological perspective to guide a research project (Moustakas, 1994). These processes are summarised below.

Epoché

The concept of suspending judgement and setting aside our own prejudices is necessary for any empirical research process. Phenomenological research acknowledges that our sensing, measuring, and judging presence is the mechanism that underpins all our research activities, from the research design, through to data collection, analysis, and synthesis. In order to empower myself as a sensing and sense-making entity, I must put aside pre-judgements and prejudices through an *epoché* or bracketing process so that the phenomenon can be encountered in and of itself.

> *The challenge is to silence the directing voices and sounds, internally and externally, to remove from myself manipulating or predisposing influences and to become completely and solely attuned to just what appears, to encounter the phenomenon, as such, with a pure state of mind.* (Moustakas, 1994, p. 88)

To achieve this state, I need to engage in a meditative process of reflection, noticing opinions, judgements, and observations that relate to the subject, but are not derived directly from my own sensory experience with the subject. As these prejudices and preconceptions are identified, I then label and note each so that I am capable of distinguishing between them, and what is revealed through my own direct encounters with the subject (Moustakas, 1994).

The epoché or bracketing process is of particular importance in this research as I have an in-depth and personal experience of the phenomena under investigation. The inclusion of my creative practice into the research design through a process of reflection provided a framework and process for capturing, labelling, and communicating preconceptions and judgements. Once I had articulated my own experiences and reflections, I found I was able to more easily identify moments in the analysis process where my own conceptions threatened to overshadow or skew my understanding of the data I had gathered. This epoché process enabled the definition and separation of my own experiences with a modular synthesiser from the experiences of others related to me through the interview process.

Phenomenological Reduction

Following the epoché process, the task is then to identify and record descriptions of the phenomena. The phenomenological reduction process seeks to first notice and record all available descriptions without judgement or analysis so that the essential nature of the experience can be revealed.

> *Phenomenological Reduction is not only a way of seeing but a way of listening with a conscious and deliberate intention of opening ourselves to phenomena as phenomena, in their own right, with their own textures and meanings*. (Moustakas, 1994, p. 92)

Moustakas describes a process of horizonalisation, where each piece of information is given equal weight, and the researcher seeks through open-ended, non-directive questioning, to explore a particular perspective that is offered by the interview subject (Given, 2008; Moustakas, 1994). The concept of a *horizon* is invoked to acknowledge that the researcher can never exhaustively capture the entirety of the subject's perspective. Each horizon or perspective adds something to our understanding of the phenomena, revealing new details and insights from different angles (Moustakas, 1994). The process is repetitive, looking or listening again and again, to filter ever more deeply, in order to capture every nuance of experience available, with the intention of uncovering the essential nature of the experience.

As descriptions are identified they are gathered together into groupings, or codes, where the descriptions are sufficiently similar to be considered a description of the same component of the phenomena, building greater detail and depth into its characterisation. This process draws upon and gathers relevant descriptions from multiple subjects where sufficient commonality is interpreted to exist (Given, 2008). A particular component of a subject's response can be coded to multiple description codes if it is interpreted to contribute to multiple descriptions of the experience's qualities.

These descriptive groupings are in turn clustered into thematic categories to denote identification and interpretation of a particular quality of the phenomena being examined. Themes remain grounded in the descriptions encountered or drawn from subjects through the interview or observation processes, and typically morph and develop throughout the categorisation and analysis processes as the researcher's understanding of the phenomena develops.

Themes are systematically organised into categories that denote components of the experience. The process of categorisation is generally distinct from processes of

synthesising or interpretation, the function being to enable themes and their component descriptions to be organised and easily accessed in the analysis process.

The following example drawn from this research illustrates the reductive process as applied to a single description code. Drawn from four different participants, these coded descriptions were interpreted as accounts of the instrument itself having agency in the composition process. The resulting description code *instrument agency* was then organised under the theme *discovery and co-creation*, with other descriptive codes such as *discovery*. The theme *discovery and co-creation* is organised under the category *composition and performance* so that throughout the processes of analysis and synthesising, the theme and its constituent codes could be reliably found and drawn upon where relevant.

Participant	**Description**	**Description code**	**Theme**	**Categorisation**
P2	"*And it was the idea, the idea of the control that's slipping in slipping control is the… control source or the voice that's leading. Um, that's determining, how a composition is taking form. And as I was working across different mediums, the thing that would kind of function as that control would shift or slip. And so it's almost like, um, how you order things within, like, if you think of a patch as like kind of an ordering of control, um, and an influence in what folds back and re-influences within a patch.*"	Instrument agency	Discovery and co-creation	Composition and performance

Table 1. Thematic coding example

Imaginative Variation

Moustakas describes the process of Imaginative Variation as a means to identify the causes and precipitating factors leading to the experiences that have been identified through the phenomenological reduction process (Moustakas, 1994):

> *The uncovering of the essences, the focusing on pure possibilities, is central in the Imaginative Variation process. In this phase of the process the structures of the*

> *experience are revealed; these are the conditions that must exist for something to appear.* (Moustakas, 1994, p. 81)

The process relies upon intuition and imagination, as intimated in its title. The work remains grounded in the experiences identified, as it is the descriptions and themes that have been gathered and constructed that the process is concerned with. However, the understanding sought – that of essential structures that lead to, enable, and cause, the experiences to occur – is unlikely to be only available through the experiencing of the experience. By separating out and linking experiences through description, and aligning experiences with commonalities through themes, understandings of structural causation can emerge.

Moustakas describes Imaginative Variation as a four-step process. The first step calls for methodically considering a range of possible structural causations. The second seeks to identify the underlying themes and contexts driving the phenomena. The third considers broader universal factors that might be relevant to the phenomenon, such as time, space, materiality and social contexts. The final step seeks out concrete examples drawn from the Phenomenological Variation process that support and illustrate the structural themes identified (Moustakas, 1994).

Synthesis of Meanings and Essences

The final component in the phenomenological research method described by Moustakas is the development of unified statements that integrate the structural themes and descriptions (Moustakas, 1994). These *essences* are in effect the end product of the phenomenological research process, offering overarching accounts that combine the what, why, and how of the phenomenon to make sense of the experiences under examination.

Concluding Methodology

This chapter has identified phenomenology as a research practice as the overarching approach to guide the methods of inquiry selected for the resolution of the research questions. In utilising this approach, my methods of inquiry include both engagement with others and reflection on my own practice. In the following chapter, I elaborate the specific methods employed to generate the data that has enabled the research questions to be answered.

Chapter 3. Methods of Inquiry

Introduction

The emphasis of my research question, understanding, describing, and analysing subjective experiences of using modular synthesisers suggests a research approach capable of capturing and synthesising the multiple subjective experiences of modular synthesiser users. The phenomenological approach and research processes described in the previous chapter provide such an approach and form the architecture of the research design for this project. To achieve my phenomenological intentions, I employed a number of specific methods of inquiry to facilitate the collection and analysis of empirical materials. Details of these are described in this chapter.

This chapter, in explaining my practitioner interview design, methods, and techniques, and the role of my practice in the research, highlights pertinent ethical issues and shows how the research methods have been designed to produce valid and trustworthy data and conclusions.

In undertaking this research, I have drawn on two specific research methods that, in my view, support my phenomenological inquiry. Notably, I explain my use of Reflective Practice (Schön, 1983) and Contextual Inquiry (Holtzblatt & Beyer, 2016) as methods that align with and support a phenomenological approach, in that they offer a means to uncover and describe lived experience. In both cases, these methods offer further guidance that enables greater detail and depth of description to be captured within the overarching framework of phenomenology.

The following table illustrates the processes and methods utilised in the research, mapping them to the processes described by Moustakas and Schütz and identifying the descriptions and accounts of these processes within the dissertation.

Phenomenological research methods and concepts	**Research process**	**Methods of inquiry**	**Account in dissertation**

Epoché	Creative practice, literature search, literature review	Reflective Practice	Background and literature review, Creative Practice - Reflective practice insights
Phenomenological reduction, identification of ideal types (thematic description)	Practitioner interviews, interview analysis, thematic coding	Contextual Inquiry	Practitioner interview data analysis
Imaginative Variation	Interview analysis, discussion		Discussion
Synthesis of meanings and essences	Write-up of discussion		Discussion

Table 2. Mapping of methods to processes and documentation in dissertation

Empirical Research and Analysis

The following describes the approaches and processes undertaken to gather and analyse empirical data to enable the research to draw upon the experiences of other modular synthesiser musicians. As this research was impacted by COVID-19 protocols, I begin with a brief caveat, setting out the impact of the COVID-19 protocols on the data-gathering processes.

COVID-19 Impact on Interviews with Practitioners

The practitioner interviews were initially designed to be undertaken entirely in person (face to face) utilising a contextual inquiry method, working with practitioners accessible in Australia or internationally through travel undertaken during the project. Shortly after the initial interviews began in early 2020, the COVID-19 crisis began to emerge, and various health regulations including social distancing, closure of interstate borders, local travel restrictions, and the halt to international travel, impacted upon the original design of the interview process.

Once it became apparent that these restrictions would be in place for at least some months, the original interview method design was revisited to incorporate the option of interviewing

participants remotely using Zoom video linking. This adjustment allowed the project to move forward with the interview process over 2020.

The shift to remote interviews made the use of contextual inquiry more difficult and at times awkward, I requested where possible that interviewees position themselves and their camera in such a way that they could still ‘show me’ things as they described them. I also requested a photo of their instrument so that I could better interpret their interactions with their instrument as I analysed the recorded interviews.

The intention to travel to the US and Europe in order to conduct interviews was abandoned due to COVID-19 travel restrictions. However, the incorporation of remote interviewing into the method design opened up the option to conduct interviews with participants anywhere in the world. Whenever possible, interviews with local artists were conducted in person during periods when social distancing or domestic travel restrictions were eased.

Practitioner Interview Design

The practitioner interviews were designed to elicit information in response to the goal of this project: To examine and describe how modular synthesisers are used, how the experience impacts upon the processes of music making, and why the experience is valued by musicians.

The following questions form essential components of the inquiry project, and therefore comprise, what I have termed, the Component Inquiries of the interview:

- How do musicians use modular synthesisers?
- How do users describe the experience?
- What attracts users to the process? What do they hope to achieve? What do they value in the experience?
- Is there a shift in the users’ intentions of music making due to modular synth use?
- How is the experience of using a modular synthesiser distinct from other composition processes they might undertake?
- How does the modular synthesiser support the processes and experiences described?

The participant interviews were designed with two distinct sections: Part One, which was conducted using a semi-structured (Thyer, 2010, ch. 18) model; and Part Two, using the Contextual Inquiry technique (Holtzblatt & Beyer, 2016). Both components of the interview were conducted in the same session.

Each interview was video recorded to enable the analysis process to incorporate the physical actions and representations offered by the participants. In the case of face-to-face interviews, a pair of cameras were used to simultaneously capture the use of the instrument as well as the participant. Remote interviews conducted using Zoom were recorded using Zoom and a screen recording as a backup.

Interview Design Part One

Part One was designed to cover predefined territory, using a semi-structured approach (Thyer, 2010, ch. 18) to ensure a level of consistency between the information gathered from each subject, while ensuring the process was open to surprising and unforeseen responses and views that might generate new tangents.

The interview questions were designed as open, broad and conversational inquiries that would elicit natural responses to the component enquiries of the research question, without explicitly asking questions that might lead participants to particular responses. A checklist was used to ensure the participant had effectively answered the component inquiries, with various follow-up prompts or probes to ensure the intention of the inquiries were covered.

The following table lists the questions asked in each interview and how they relate to the component inquiries:

Table 1. Semi-structured interview plan.

Component Inquiries	**Interview Question**	**Intention / Prompts / Probes**
How do musicians use modular synthesisers? How do users describe the experience? What attracts users to the process? What do they hope to achieve? What do	What have you been working on with your modular lately?	• Enables the respondent to identify a recent project or activity as a starting point for the discussion. • If it becomes apparent that the activity described is atypical of their approach, they can then be prompted to describe an activity they would identify as being a better representative of their practice. • Probe to understand how musical events are generated in their process, i.e., sequenced by a computer, step sequencer, clock dividers, etc. • Probe to understand why they undertake this approach.

they value in the experience?		• Identify and note aspects to cover in Part Two of the interview.
	Talk me through how you would typically be set up to record or perform?	• If not already covered in the above question. • Probe to understand where the modular sits in their process and what other equipment and systems it is interacting with, i.e., laptop, mixer, MIDI, DC offset audio interface, plugins, pedals, other hardware synths, external sequencers, etc. • Probe to capture the relationship of patching to performing or playing, and if there is a differentiation between these processes. • Probe to understand why they undertake this approach.
	Talk me through your instrument and its modules?	• If not already covered in the above question. • Identify and note aspects to cover in the contextual inquiry stage of the interview. • Probe to understand how musical events are generated in their process, i.e., sequenced by a computer, step sequencer, clock dividers, etc.
Is there a shift in the user's intentions of music making due to modular synth use?	How long have you used a modular synthesiser?	• Build an understanding of where their use of a modular synth fits into their engagement with music making. • Probe to determine what initially attracted them to using a modular synthesiser.

How is the experience of using a modular synthesiser distinct from other composition processes they might undertake?	How did you make music previously?	• If not already covered in the above question. • Probe to determine if any changes can be identified in relation to the generation of musical event, i.e., aspects of indeterminism, improvisation, use of systems, feedback, etc. • Probe to understand how they identify the modular is different than previous approaches.
What drives them to use a modular synthesiser?	What makes you want to use a modular synthesiser?	• Ground this answer in the components of the instrument, identify supporting relationships or seeming contradictions. Probe to clarify. • Probe to understand how they identify the experience of using the modular is different from previous approaches.

Table 3. Mapping of interview questions to research inquiry

In practice most component inquiries were covered by the participants responses without the need for follow up probes. In some cases, the first question would elicit a long response of 20 minutes or more that covered all component inquiries of the research question. This eagerness of participants to share their ideas and experiences might be due to the inquiry relating to an experience they are passionate and excited about. Had I sought to understand their experiences of using a dishwasher or refrigerator, I assume less detail may have been volunteered and prompting inquiries more frequently deployed.

Interview Design Part Two

The compositional process is largely internal, requiring personal and subjective interpretation to be communicated. The process may also be informed by tacit knowledge that resides beyond the grasp of an individual's conscious reflective process (Zembylas & Niederauer, 2017, p. 1). The practitioner interview data gathering process was designed to capture the subjects' reflective interpretations of their compositional processes through dialogue, while also employing *contextual inquiry*, a design research method that can assist in uncovering and articulating unconscious processes and tacit knowledge. For Interview Design Part Two the focus was on using contextual inquiry.

Contextual inquiry situates the researcher in the relevant environmental context of the subject and activity, emphasising close examination of the processes undertaken by the subject using a master and apprentice relationship model, where the researcher explicitly

situates themselves as a learner seeking knowledge from the participant or subject (Holtzblatt & Beyer, 2016). Through a process of observing the activity first hand and probing the subject about their actions, the researcher can access information about the process that may be missed in an abstracted summarisation, such as visible emotional responses, interactions with the broader environment, and decision-making processes and the motivations behind them. This partnership is two way and extends to checking the researcher's interpretations with the subject during the interview, enabling a continual process of correction and adjustment. The practitioner interviews were designed to situate the subject with their modular synthesiser, preferably in the environment they normally work in. Subjects would be encouraged to demonstrate ideas and approaches they have referred to in dialogue during Part One of the interview.

In this second stage of the interview, the participants were asked to show me a process or technique they had mentioned in the first stage of the interview. Starting with their instrument unpatched, participants were encouraged to 'think aloud', describing their actions and intentions as they create the patch (Boren & Ramey, 2000; Ericsson & Simon, 1993). This stage of the interview was a dynamic and open-ended process of discovery, and as such, specific questions were not formulated in advance. The process of the interview was intentional, with the following guidelines employed:

> Keep the participants grounded in the actions they are undertaking. Discourage them from speaking in abstractions or summarising by directing participants back to the instrument and the process of them demonstrating what they would do physically (Holtzblatt et al., 2004).
>
> Situate myself as the apprentice or learner, and the participant as the teacher or expert (Holtzblatt et al., 2004).
>
> Check understandings of their actions with the participant to prevent assumptions regarding their process or intentions (Holtzblatt et al., 2004).
>
> Be upfront about what aspects demonstrated are of particular interest to the research. This will assist them to identify relevant examples. (Holtzblatt et al., 2004).

As shown in Table 2, the practitioner interviews correlate with the process of Phenomenological Reduction.

Sampling and Recruitment

The qualitative nature of the research inquiry calls for a non-probabilistic approach to identifying and selecting participants for the study. The intention to describe a diverse range of experiences rather than establish a generalisable statistical finding led to the adoption of a combination of convenience sampling, snowball sampling and purposive sampling techniques (Given, 2008).

Due to my involvement with modular synthesisers, essentially operating as an insider researcher, I was well positioned to identify and approach participants to be interviewed. Known as *convenience sampling*, due to the relative ease of the availability of subjects, this approach can bring a risk that I might only interview those who might reinforce my own views or experiences as we are connected to the same communities. Around half the participants interviewed were people who I already knew and had met on previous occasions. Due to my involvement in various modular synthesisers focused online communities and my experiences running the *Moduluxxx Festival of Modular Synthesis* in 2012 and 2013 (*Moduluxxx 2012 by Alex White - Pozible*, n.d.), I could have continued to draw upon these connections for the entire study. However, the people I selected were purposely chosen as they offered a diversity of approaches, musical styles, and personal backgrounds, as well as connections to communities outside of my own networks.

Each participant interviewed was also encouraged to suggest other interview subjects whom they thought might be interested, or who would broaden the diversity of experiences represented in the study. Referred to as *snowball sampling*, this technique allowed the study to include participants from outside of my own communities and connections. Snowball sampling also carries a risk that a biased portion of the potential population of participants might be selected; however, the diverse range of participants initially selected works to counteract this risk (Given, 2008, p. 816).

To ensure a broad range of approaches and experiences were covered, participants were often selected if it seemed likely that they would contribute new perspectives due to the style of music they make, or role the modular synthesiser plays in their live or studio practice. This exemplifies a purposeful approach to sampling. In addition to participants already known to me, or suggested by other participants, some participants were identified through social media accounts where they shared performances. Female and non-binary identifying respondents were emphasised in this process to ensure gender diversity and assist the research to be more broadly relevant.

A small number of participants were selected because of their experience with modular synthesisers prior to the contemporary resurgence, with some involved in the initial development of early instruments such as the Serge or Buchla. These historical perspectives allowed the project to reflect upon the relationship of contemporary modular synthesisers to historic instruments.

In total, 21 participants completed the interviews: 11 male, 9 female, 1 non-binary. The table below provides a short description of the musical style or approach employed by each participant. While these descriptions are brief and simplistic, they do provide an overview of the kinds of musical applications of the modular synthesiser in current practice and also provide context to the participants' responses.

ID	**Recruitment method**	**Gender**	**Style and Approach**	**Remote or in-person interview**
1	Convenience	M	Diverse music styles from dance music to abstract ambient. Stand-alone use of modular synthesiser.	In person
2	Snowball	M	Experimental and conceptual approaches. Modular used in conjunction with laptop patching software.	Remote
3	Purposeful	F	Dance music and ambient. Stand-alone use of modular synthesiser.	Remote
4	Snowball	F	Dance music and experimental electronic. Modular used in conjunction with laptop-based Ableton Live.	In person
5	Convenience	M	Abstract experimental music. Stand-alone use of modular synthesiser. Emphasis upon sampling and mixing in the modular.	In person

6	Convenience	M	Abstract experimental music. Stand-alone use of modular synthesiser. Emphasis upon melodic and rhythmic systems.	Remote
7	Purposeful	M	Historically significant musician linked to the development of the first modular synthesisers. Abstract experimental music. Use of Buchla in conjunction with tape music practices.	Remote
8	Convenience	M	Abstract experimental and dance music. Stand-alone use of modular synthesiser. Emphasis upon live improvisation and patching.	In person
9	Purposeful	F	Abstract experimental. Stand-alone use of modular synthesiser. Emphasis upon DIY module building.	Remote
10	Purposeful	F	Dance music. Modular synthesiser used in conjunction with other hardware instruments.	Remote
11	Convenience	M	Abstract experimental music. Stand-alone use of modular synthesiser. Emphasis upon live improvisation and patching.	Remote
12	Convenience	F	Abstract experimental music. Use of semi-modular instruments with CV control in conjunction with laptop-based Ableton Live.	Remote

13	Convenience	M	Abstract experimental and industrial music. Emphasis upon live improvisation, use of DIY modules. Stand-alone use of modular synthesiser.	Remote
14	Snowball	F	Abstract experimental. Emphasis upon live improvisation. Stand-alone use of modular synthesiser.	In person
15	Purposeful	F	Historically significant musician. Sound design and various music styles. Use of modular instrument, in particular Serge.	Remote
16	Snowball	N	Abstract experimental and various electronic music genres including ambient and industrial. Emphasis upon sound design. Modular synthesiser used in conjunction with other hardware instruments.	Remote
17	Convenience	M	Electronic dance music. Stand-alone use of modular synthesiser. Emphasis upon live improvisation and patching.	In person
18	Snowball	F	Ambient music. Modular synthesiser used in conjunction with other hardware instruments. Emphasis upon repeatability and digital modules.	Remote
19	Convenience	M	Experimental dance music. Stand-alone use of modular synthesiser. Emphasis upon live improvisation and patching.	In person

20	Purposeful	F	Dance music. Modular synthesiser externally sequenced by software. Emphasis upon traditional synth voices.	Remote
21	Purposeful	M	Historically significant musician. Abstract and ambient music. Use of a broad range of historical and contemporary modular instruments.	Remote

Table 4. Interviewees overview

Interview Analysis

Video recordings of each interview were transcribed and then loaded into Nvivo qualitative data analysis software. The transcription and video files were linked in Nvivo so that throughout the analysis process the participant's actions and responses could be encountered through video and sound, and the transcribed responses coded on a word-by-word basis.

Each interview was reviewed multiple times, firstly in order to correct any issues in the transcription file, then to code components of the interview as descriptions, and finally, to thematically organise the coded descriptions. As the interviewing process progressed and data from more participants was encoded, these codes and themes shifted and morphed in response to the broadening set of data.

In terms of phenomenological inquiry, the interview analysis incorporates the processes of Phenomenological Reduction and Imaginative variation (see Table 2). A full account of the themes and descriptions identified is provided in Chapter 5.

Role of Practice

As explained previously, the line of inquiry pursued in this research arose through my creative practice, which, since 2011, has focussed on the use of modular synthesisers for composition and improvisation. With the goal of this project being to seek to understand how modular synthesisers are used, how the experience impacts upon the process of music

making, and why the experience is valued by musicians, the research can be described as practice-led, as the inquiry has come about through practice (Gray, 1998).

While the production of artefacts through creative practice forms a key component of the research design, my own creative practice is not the subject of the research. This approach eludes the definition proposed by Candy (Candy & Edmonds, 2012, p. 37) where "practitioner research is primarily directed towards understanding and improving an individual's practice and its outcomes". While I hope that the research process will lead to improvements in my practice, this is not the primary intention of the research. Instead, the objective is to identify and discuss phenomena that are significant and relevant to a broader community of practitioners (McNamara, 2012, p. 6).

I have drawn upon the work of Donald Schön in understanding the contributions to knowledge and perception possible through reflecting upon the experience of process or action, both whilst undertaking the process and after undertaking the process (Schön, 1983). Schön's seminal text, *The Reflective Practitioner* (1983), provides an analysis of approaches undertaken by practitioners in a range of professions, drawing attention to the skills and knowledge garnered through the act of undertaking their practice. Schön's concept of reflective practice, while not a method per se, has still contributed to both the framing and valuing of my own experiences with a modular synthesiser.

My engagement in creative practice and reflection on this, (together with the literature review) constitute, in phenomenological inquiry, the process of Epoché (see Table 2). Thus, my creative practice has contributed to my research process by enhancing concept generation, understanding, and interpretation, and providing transparency as described below.

Concept Generation

The processes of creation and reflection in action (Schön, 1983) surfaced concepts and possibilities that I found to be surprising and compelling. Following Smith and Dean (2009), I view the relationship between my creative process and the traditional empirical research activities of theorisation, articulation, data gathering, research methodology planning, and data interpretation to be cyclic and bidirectional. Over the course of this research project, through a process of action and reflection, the development of new performances and recordings has assisted in generating ideas and concepts in concert with reflections on the ideas raised by research participants.

Understanding and Interpretation

As the project engages with other practitioners, my creative practice allows me to try key aspects of the interview participant's approaches, with the intention of building empathetic understandings of their intentions and motivations. Modular synthesisers can be complex, and each artist's instrument is a unique configuration of modules that offers a seemingly endless range of possibilities. Even as an insider researcher this is a challenging subject in which to find and confirm common understandings and descriptions. Despite this, the process of analysis and interpretation of compositional processes will be greatly aided by hands-on, reflective, and contextual analysis through my creative practice.

Transparency and Epoché

The inclusion and analysis of my own experiences of working with a modular synthesiser also provides a mechanism for me to be explicit about my interpretations of my own experience. As a researcher I cannot realistically bracket off my experiences with modular synthesisers; however, by describing my own interpretations I was aware of these subjectivities, and the reader is also able to take these into account in their own consideration of the research presented.

Portfolio of Works

A portfolio of recorded works and documented live performances accompanies this dissertation as detailed in the Creative Practice Appendix and described in Chapter 4. Taking onboard Scrivener's (2002) point that framing an artwork as a form of knowledge is problematic and reductive of the implicit value of an artwork, these documents are presented as a product of my creative practice and above all else indicative of those processes. Working in concert with the descriptions of the processes undertaken in my creative practice, these works provide an illustrative mechanism to enhance the reader's understanding of the phenomenon under examination – in other words, how I use the modular synthesiser, how this impacts on my processes of music making, and why I value this experience.

Ethical Issues

The research outlined poses minimal risks as it does not target any vulnerable communities, nor does it pose any particular risk of harm to either myself or the participants. The following processes and measures were undertaken in the research process to address specific ethical concerns.

Privilege

As identified in the positionality section of this document, I come to this project from a position of privilege, which brings with it a risk of perpetuating historical trends in the music technology field that under-represent and marginalise non-white, non-male, non-Western and non-heterosexual contributions. Throughout this research project I have purposefully sought out respondents, examples, and peers who can contribute to an understanding of the research space that is inclusive and diverse so that any histories that this work contributes to do not further distort or ignore the involvement of contributors that are not cisgender, white, heteronormative men.

Bias and Subjectivities

As an insider researcher there is a particular risk of confirmation bias for my interpretations, ignoring my tacit understandings, and working with participants with whom I already am familiar. In the positionality section of Chapter 2 I have acknowledged the interpretations I have reached through my practice. The inclusion of practice as a component in the research process gives a dedicated space for my interpretations to be made explicit, assisting me to be aware of these biases in the design and analysis of interviews. Contextual design forms a key component of the interview process and is designed to balance researchers' biases, grounding the data gathering and analysis processes. Interpretations were continually checked throughout the interviews to allow correction by participants.

Informed Consent

An information sheet was provided to all prospective interview subjects that outlined the intentions of the research and the participants' proposed involvement, making it clear that participation was voluntary and that participants could withdraw from the interview process at any point. Interpretations were shared both in the interview process itself and on some occasions in writing to check the accuracy. Participants could also agree for edited versions

for the interviews to be made publicly available to encourage broader discourse in the subject area and community. At any point these would be removed at the participants request. The Information Sheet is included in the Appendix.

Peer Review

The interview design was reviewed and approved by the Human Ethics Research Committee of the University of Technology Sydney (approval ETH19-3792). A copy of this is included in the Appendix.

Validity and Trustworthiness

A range of considerations are necessary to ensure the results of a qualitative study are of publishable standard. Drawing upon the work of Elliott, Fischer and Rennie (1999), the research design addresses the following to ensure the research and its findings are valid and trustworthy.

Disclosure of Researcher’s Perspective

The intuition, interpretation, and assumptions of the researcher are a critical component of any research process. In the case of qualitative research, and specifically phenomenological methods, this is particularly true. In order for readers to interpret the data and findings it is necessary for the researcher to recognise and disclose their own values, interests, and assumptions (Elliott et al., 1999). Chapter 2 includes a section devoted to positionality, which reveals my understanding of what knowledge is and how it is known, my biases and subjectivities. The inclusion of my creative practice through a process of reflective practice (Schön, 1983), documented in Chapter 4, provides an explicit and detailed description of my experiences with modular synthesisers.

Situating the Sample

Relevant information about the context of the research participants' life circumstances assists a reader to assess the data presented (Elliott et al., 1999). Chapter 5 begins by providing general information about the range of life circumstances represented by the research participants. This is then expanded upon through descriptions of the varying

contexts in which the participants use a modular synthesiser. By clearly situating the sample group, the reader may better determine the scope of validity of the data collected.

Grounded in Example

By providing verbatim examples of the data gathered, a researcher is able to demonstrate the logic and sense of the analysis and findings presented (Elliott et al., 1999). Throughout Chapter 5, participant quotes are provided to illustrate significant themes. The anonymised designation (Participant 1, Participant 2, etc.) of each subject is provided in relation to a theme or quote to indicate a concrete link back to the data. This allows a particularly investigative reader to correlate descriptions without simply exposing the entire data set or revealing the identity of the participants. Case studies are also provided to illustrate specific processes demonstrated by the participants so that readers can draw upon the concrete actions as well as the abstract description provided by participants. This grounding is intended to enhance the trustworthiness of the analysis.

Credibility Checks

In order to ensure the credibility of their data and analysis, a researcher can employ a range of approaches, including checking their understandings with the participant or triangulating data from multiple subjects (Elliott et al., 1999). Throughout the interviews I checked back with participants to ensure my interpretation of their actions and intentions was correct. Wherever possible the responses of more than one participant were drawn upon to form thematic findings. In cases where this was not possible, I have indicated that the finding is based upon a single respondent.

Coherence

There is a balance involved in the representation of the underlying data, the description of the themes, and the understanding developed through the analysis process (Elliott et al., 1999). If a reader is not provided with a framework or narrative that draws the findings and data together into a coherent structure that can be navigated and comprehended, then the reader may not be able to engage with or understand the thematic findings. Throughout my discussion of interview data in Chapter 5, the research findings are organised across broad themes to enable the reader to navigate and conceptualise the information presented. Similarly, Chapter 6, “Discussion”, is organised into major thematic findings to provide a

narrative that relates the logic, significance, and interpreted meanings drawn from the data analysis.

Transparency of Limitations

A researcher should not overextend their representation of their understanding of a phenomena by representing a specific instance as a general understanding, or by extending the understanding to contexts outside the remit of the research (Elliott et al., 1999). Throughout this dissertation I have specified when a thematic understanding has significant grounding in multiple participants accounts, and where the finding is based upon a single account. The major thematic findings described in Chapter 5 draw upon multiple themes, which in turn are based upon multiple triangulated accounts. In cases where I have suggested broader implications beyond the scope of the research, the limitation is disclosed.

Concluding Methods of Inquiry

In this chapter I have outlined the methods and techniques of inquiry appropriate to furthering my phenomenological intention of understanding, describing, and analysing subjective experiences of using modular synthesisers. I have shown how the empirical data collection, achieved through non-probabilistic selection, practitioner interviews, and interview analysis processes, together with my reflective and creative practice, were necessary and appropriate to my project and how these activities map against the phenomenological research processes described in Chapter 2. The chapter also presented the limitations and pertinent ethical considerations of the research process, together with a systematic approach to consideration of the validity and trustworthiness of the research.

Overall, this chapter has shown the appropriateness of combining reflective practice and my creative practice with the carefully garnered diverse perspectives of a range of practitioners, to provide a complex and nuanced description of my phenomena of interest: understanding, describing, and analysing subjective experiences of using modular synthesisers.

Chapter 4. Creative Practice

This chapter recounts my creative practice and its contribution to my research. Beginning with an account of my journey to using a modular synthesiser, I then describe a range of creative approaches undertaken and their recording or performance outcomes. Key compositional systems are then detailed. The chapter concludes with a range of insights into my experiences of working with a modular synthesiser. By examining my own creative practice in a more or less systematic way, I aim to give an example of how modular synthesisers are used, how the experience impacts upon the process of music making, and why the experience is valued by myself and other musicians who have adopted the modular.

My Journey to Modular

My involvement with electronic music began in the late 1990s with a range of analogue equipment, shifting to a computer-based set up in 2000. I eventually began using a modular synthesiser in 2011. An account of this evolution and my experience of making this shift is provided.

Roland JX-3P to Laptop

I first became involved in making electronic music when I sold my Datsun 1600 station wagon to buy a second-hand Roland JX-3P keyboard in 1996. I had a friend who was studying music at the University of Western Sydney, and he had begun playing electronic music with friends using combinations of old synthesisers, drum machines, and samplers. I had wanted to try making electronic music for some years, as much of the music I listened to was industrial, techno or drum and bass. The JX-3P enabled me to join him and other friends in informal jam sessions where one person might have a Roland TR-606 drum machine, another a Roland SH-101, and perhaps a delay pedal between us. During this time I did borrow a friend's 4-track recorder and recorded some material, but the leap to recording and finishing a piece of music seemed insurmountable with the limited equipment to which I had access.

At this time home computers were just beginning to become capable of real-time audio and virtual synthesis. In 1998 my friends managed to access a copy of Propellerhead’s Rebirth, a software emulation of a pair of Roland TB-303 synthesisers and a TR-808 drum machine. This opened up the possibility of producing music that would otherwise not have been possible without many thousands of dollars worth of vintage equipment. Two years later, a

friend showed me a demo of Native Instruments' Reaktor, a software-based visual programming language that enabled the construction and modification of electronic music equipment including synthesisers, samplers, sequencers and effects. Within weeks of encountering Reaktor I customised my own instruments and began recording segments that would later be constructed into my first finished pieces using a free version of Pro Tools. Reaktor became my primary instrument for many years, initially to make techno (Autoclave, n.d.), and later to perform various iterations of noisy, freeform electronic music.

In 2002 I enrolled in the newly formed Bachelor of Electronic Arts at the University of Western Sydney. The course enabled me to major in music production technology, while also learning video and animation from a fine arts perspective. While studying there I encountered the practices of a range of experimental music makers including Robin Fox, Jim Denley, Peter Blamey, Joyce Hinterding, David Haines and Gail Priest. My interests firmly shifted to experimental and improvised music, performing and organising in the small scenes Sydney offered. I identified as a laptop-based musician or artist; I was interested in how a laptop might be performed with, but also what the nature of a laptop was as an 'instrument'.

Alongside my laptop-based efforts, I also maintained an interest in analogue hardware. I would perform with a large Hewlett-Packard valve-based test oscillator, and an old Tama Techstar electronic drum module, feeding each into the other to form complex and unstable feedback loops. I loved the warmth I perceived in those analogue instruments and the potential for feedback in the analogue domain, as equivalent approaches undertaken with software would often lead to my computer crashing, a harsh digital distortion, or continuous tone.

Move to Modular

I was aware of modular synthesisers as historic instruments, and of the more recent Doepfer A-100 (Doepfer A-100, n.d.) series modular, but I had previously felt these instruments were outside of my budget. In late 2010 I had separate conversations with two friends who had decided to begin building Eurorack modular synths and I began researching them in earnest. In early 2011 I ordered my first case and a handful of modules. My plan was to minimise costs **by** focusing on sound-focused components: two oscillators, a dual filter, and a VCA. I bought an Expert Sleepers ES-3, a module that could produce DC offset signals from a computer via an ADAT lightpipe connection. This enabled me to produce up to eight modulation sources from Reaktor. I intended to build patches in Reaktor that would control the small modular, with the audio itself being a pure analogue signal.

In the process of investigating the Eurorack format I had engaged with several online forums, such as the Modwiggler website (Mod Wiggler - Index Page, n.d.). Through the forum I became aware of the Make Noise MATHS module (Make Noise Co. | MATHS, n.d.), and although my plan had been to conduct all modulation via software, I decided to also buy a MATHS in order to understand some of the concepts I was encountering on the forum. My experience of the hands-on immediacy of the MATHS module in comparison to patching within Reaktor convinced me that I was not experiencing the full potential of the modular synthesiser as an instrument in itself when attempting to use it as a hybrid software instrument. I received an Australia Council for the Arts grant later in 2011 and used much of the grant funds to purchase a range of modules so that my modular set-up could be used as a stand-alone instrument.

While I initially explored a range of approaches to using the instrument, in retrospect I believe I was somewhat lost and directionless. My experiences of patching with software only partially translated to the modular; the limited number and types of modules meant that some ideas were not possible. Changes to my intentions were much slower and more expensive to implement, and as the configuration of the instrument shifted toward a specific approach, the capacity to explore other possibilities diminished.

In 2012 I attended a performance by Keith Fullerton Whitman as a part of Time Machine festival (Serial Space, n.d.) presented by Serial Space in Sydney. At the time Whitman was performing with a large, but still portable Eurorack modular synthesiser, performing his piece *Occlusions*. Over thirty or so minutes the piece built up from seemingly disparate atonal clunks and bleeps into a mass of squeaks that had no regular meter or discernible structure. However, *Occlusions* seemed to build up its own logic or language that made every unpredictable atonal squark seem to be absolutely correct. Something about the way in which the piece's rhythms operated flicked a switch in my brain. I felt like I understood something that a modular synthesiser could uniquely offer from its own nature and form: a fluid generation of musical structure through complex systems.

Nadir

Much of my creative efforts from 2011 to 2016 were focussed upon a duo formed with my friend Ben Byrne, under the name Nadir (White, n.d.). Ben's own practice is largely laptop based, with a particular interest in manipulating found sound sources in real time. For Nadir, I improvised with my modular, the output of which Ben would then process and manipulate using a laptop running Pure Data patches he had developed. Both the original and the manipulated sources were then mixed together for recording and live improvisation. Between

2011 and 2016 we performed many times and released a number of EPs and a self-released vinyl record, *Excessive Redundancy* (Nadir, 2016).

Nadir is ostensibly a ‘noise’ project, but we were interested in trying to address concepts of noise in a broad sense, consciously steering away from genres of noise music such as Power Electronics, where the music seems to operate as an attempt to shock or evoke a sort of sonic violence (Newall, 2011). While Nadir would sometimes produce harsh or noisy timbres, we were more interested in addressing the idea of noise as masses of complex, meaningless repetition overwhelming any one ‘signal’. The systems I devised often utilised forms of feedback, but the feedback occurred in the generation of musical events rather than audio feedback as a sound source. Nadir as a live duo is a feedback system in itself, with two humans listening and responding to each other's instrument, cycling continuously. Over the years we were most active, we self released many short EPs, in a deliberate attempt to be prolific, in the same way that noise is seemingly limitless and continuous.

Nadir was an important opportunity for me, as I needed to develop patches and approaches that were dynamic and responsive, allowing me to work in a flexible and improvised fashion, responding to Ben. Over the five years that we were most active, my approach gradually shifted from directly performing the instrument through physical gestures, to creating a complex generative system that I would intervene into and steer in a more abstracted way. Key components of my modular synthesiser patch concerned with generation of complex multi-layered rhythms and stochastic control of timbre were refined and reiterated over several years and many performances. Elements of my complex generative systems became key components of the patches utilised in the practice outcomes described below, in particular, the *complex programmer system component* described later in this chapter.

My journey to adopting the modular synthesiser as an electronic musician is in some ways typical for musicians of my generation. Like several of the participants in my research, for me the promise of computer-based composition and performance became unsatisfying. Over a period of a decade, the modular had become central to my performance practice, and the most recent outcomes of this are explored in the next section.

Practice Outcomes

The following recordings, performances and exhibitions were produced over the course of this research project. The processes and thinking behind each are detailed, with the reflective insights generated discussed later in this chapter. Each work is listed in the Practice Outcomes Appendix, and links to documentation and examples are provided there.

Terrible Things Have Happened to MIDI

At the beginning of this research project, I identified some broad directions that I wanted to explore as an artist, which I hoped would also stimulate my thinking in relation to my use of modular synthesisers. One of these was to focus on the possibilities for structuring music with a modular synthesiser by limiting myself to only using the instrument to produce MIDI or CV control signals that could be used to control other instruments as sound sources. I hoped that by shifting my attention away from the seemingly endless possibilities for generation of timbre with the modular I would be able to experience and focus on generating musical events and the relationships between them.

With this in mind, I incorporated an Expert Sleepers General CV (Expert Sleepers General CV, n.d.) module into my instrument, which allowed me to convert CV signals to MIDI signals and also control its own internal General MIDI (GM) synthesiser. The earliest experiments I undertook in this direction used a Waldorf Blofeld (Waldorf Music, n.d.) as the primary sound source, utilising the Expert Sleepers General CV as a CV to MIDI convertor. The Blofeld is a virtual analogue digital synthesiser that offers internal effects alongside some limited wavetable synthesis capabilities. Utilising the Expert Sleepers General CV I converted a range of CV and gate signals into MIDI notes (pitch and velocity) and MIDI control change (CC) signals.

These early experiments took an unstructured exploratory approach, seeking to understand the parameters of the relationship between the analogue signals and the reaction of the MIDI instrument. Some of these experiments were recorded, I later listened back to and edited these down to 6 tracks that I felt had achieved some interesting results. In 2021 I produced a self-released tape and digital release of these recordings titled ‘Terrible Things Have Happened to MIDI’. The release is highly abstract with many tracks exhibiting a sort of strained repetition, sometimes as a result of the Blofeld’s MIDI processor being overwhelmed by the density of the data it was fed.

Terrible Things Have Happened to MIDI (2021) is a self-published 6 track EP. See **Practice Outcomes Appendix Audio Example 1** for further details.

General MIDI Experiments

Following on from my experiences with the Blofeld I was interested in further reducing the complexity of the sound generator. The Blofeld being capable of producing complex timbres

that could shift and morph with the application of MIDI CC data, I felt that I was still struggling to focus upon the structural possibilities offered by the modular due to the complexity of the timbral generation of the Blofeld. To reduce this complexity I began utilising the internal General MIDI (GM) synthesiser built into the Expert Sleepers General CV (Expert Sleepers General CV, n.d.). The General MIDI standard (General MIDI [GM 1], n.d.) synthesiser seems likely to be the least exciting form of electronic music instrument, its standardised instrument set having been employed across a range of contexts from 1990s computer games to mobile phone ringtones in the early 2000s. For me, it represents the ultimate reduction of the potential of electronic music as a medium with its own creative possibilities, instead relegating the synthesiser to a playback device capable of only poor imitations of existing musical timbres and forms. The instrument's banality seemed an opportunity to force me to only focus upon the musical structure generating potential of the modular in an attempt to find some interesting sonic territory.

I experimented with using various complex CV sources to select the current program of the GM synthesiser embedded within the General CV module. This enabled the source to quickly, and somewhat unpredictably, switch between percussion, piano and various stringed instrument sounds. Pitch and velocity were addressed by CV from additional interrelated complex systems. Somewhat interesting material resulted, but I felt my efforts sounded much like a slightly mechanical free jazz. The range of instrument voices being engaged by this approach, and perhaps the quality of the sounds themselves, seemed to give away its cheap 'general MIDIness' nature. While my intention was not to simulate a real instrument, I found it hard to achieve anything more than what seemed like a tongue-in-cheek gimmick. To counteract that I shifted to only using a piano sound, and found that this did enable me to engage with the process more earnestly without the distraction of the banal sound library revealing itself.

The instrument patch I created included the *complex programmer patch component* described later in this chapter, to effect interrelated, divergent changes across multiple parameters of the instrument system. This enabled me to concentrate on just a few key parameters in the performance process, adjusting others as needed in relation to the changes produced by the *complex programmer patch component*. During the course of developing this work, I also established the *wavefolded pitch modulation patch component*, which I went on to modify and use in other projects. The *wavefolded pitch modulation patch component,* also described further below, formed the basis for pitch information to be generated with a significant degree of real-time control over the complex structures produced.

I engaged a pitch quantiser to interpolate and limit the CV source to specific musical scales. This shift away from largely atonal pitch relationships took an additional layer of complexity away from both the process and the outcomes I was able to achieve. The quantisation effectively corralled the chaotic CV signals into more palatable configurations, and in the process of improvising with the system I no longer needed to consider the resulting pitch relationships in terms of their tonality: I could not put a foot wrong. The removal of atonal pitch relationships limited the complexity of the resulting music in one dimension, the exclusive use of a piano's timbre had already limited the resulting complexity in another dimension. These reductions in complexity enabled me to concentrate on designing and performing complex systems which were solely concerned with the timing of musical events and relative changes in pitch and velocity.

Agatha Gothe-Snape Exhibition 2019

In early 2019 I had been asked by an artist friend, Agatha Gothe-Snape, to assist her by making some sound-based components for her upcoming solo show at Brisbane's Institute of Modern Art (Institute of Modern Art, n.d.). We were initially interested in employing binaural sound recording as part of a sculptural work she was creating and while chatting I played her some of the GM piano material I had recorded. Agatha became interested in this becoming a soundtrack for her sculptural work. I eventually abandoned my use of a GM synthesiser to instead control a higher fidelity sample-based piano software instrument via MIDI.

Through numerous improvisations and adjustments to the patch I refined my approach, as the resulting music needed to operate as a soundtrack to a performance that would be recorded and presented alongside the sculpture installation. Due to this specific outcome and Agatha Goethe-Snape's intentions and preferences, I devised the instrument system so that as a performer I could have a greater degree of direct influence over the instrument. I separated out the components of the system that determined the rate at which notes would occur so that I could respond more coherently to the actions of the performance in real time. The precise occurrence of a note event was still outside of my control, but I could increase and decrease the likelihood of notes occurring. Similarly, the system allowed the range of the pitch of note events to be limited and moved up or down. The precise pitch of the resulting note events was outside of my control, but the system as a whole enabled me to shift the instrument's output dramatically from sparse and high-pitch notes through to cavalcades across the entire virtual keyboard.

I recorded a two-hour long improvisation of mostly sparse and slow material, which was played in a loop in the gallery over the course of the exhibition. In addition, we video recorded a performance in the installation space, with Agatha Gothe-Snape and her collaborator Brian Fuata performing dialogue and movement while I improvised in the background. The performance was documented using a 360-degree camera to allow the viewer to shift their view around the space. The sound of the performance was recorded using binaural microphones, positioned upon the ears of the exhibition's curator, Madeleine King, who was seated on the sculpture itself. During the exhibition, headphones were provided to the audience when they were seated upon the sculpture, so that they could hear a virtual ghost-like rendition of the performance around them.

This work further demonstrated the creative utility and event-generation potential of the *complex programmer* and *wavefolded pitch modulation patch components*, and extended them by making them more readily performable.

The work was exhibited at Institute of Modern Art (Institute of Modern Art, n.d.) from 29 June–31 August 2019. See **Practice Outcomes Appendix Audio Example 2** for further details.

Transductions 2020

Upon finishing the composition for Agatha Gothe-Snape's exhibition I was interested in continuing to explore the possibilities for controlling a piano with the modular synthesiser. Freed from the specific requirements for Gothe-Snape's work, I wanted to shift control back from the performer to the system and take a more experimental approach with less referencing of existing musical forms. With this in mind I modified the patch so that the rate and timing of notes was influenced by the *complex programmer system component* alongside the components responsible for determining the pitch, length and velocity of the MIDI notes. This approach intrinsically linked all possible elements in the software piano instrument so that changes to the *complex programmer system component* impacted all aspects of the instrument's MIDI output in unpredictable but repeatable ways.

The process of improvising with the instrument was one of discovery, where sudden and unpredictable changes would result from minor adjustments to the waveforms feeding the *complex programmer system component*. I could then respond to these changes by manually adjusting individual module controls to guide the complex system closer to outputs

that I found aesthetically interesting. In this way the process was effectively a collaboration between the system and myself. Similar to the experience of improvising with another performer, I needed to listen and respond to what the system produced. Our decisions were entirely enmeshed together through the instrument system so that it was not possible to attribute elements of the resulting music to either myself or the machine.

Other adjustments I made were more permanent. By attenuating the *complex programmer system component's* voltage outputs and combining the signals with voltage offsets, I was able to denote ranges of control voltage to be applied to specific components. These adjustments enabled me to more confidently initiate changes from the *complex programmer system component* knowing that the results were more likely to fall within the musical territory I was interested in exploring.

Over a period of several weeks, I improvised with the system, recording both the resulting audio and MIDI note data. While the software piano instrument sounded very convincing, I became interested in hearing a real acoustic piano performed in this way. I was able to access a MIDI controllable Yamaha Disklavier acoustic piano through generous assistance from a friend at the University of NSW. As I would only have limited time with the Disklavier, I selected sections of recorded MIDI data from the improvisations that I found most interesting so that I could concentrate on recording the instrument in the time I had.

To record the piano, I used a pair of condenser microphones in an AB configuration set 30 cm apart and around 60 cm away from the instrument to emphasise the sound of the keys and internal mechanisms. As a result of the AB set-up the higher notes of the instrument are slightly emphasised in the right and the lower tones in the left side of the recording. The natural reverberation of the piano's body is also emphasised in comparison to hearing the instrument acoustically in the studio space, possibly a side effect of the AB configuration and the distance from the instrument.

Once the recording approach had been tested and adjusted, each MIDI file was played through the piano and recorded, with a short break in between each file to allow for the natural reverberation to subside. There was something uncanny or magical in the experience of listening and watching a MIDI-controlled acoustic instrument be performed. The movement of the keys themselves revealed patterns and relationships also present in the music. The vibration of the instrument's physical body seemed novel, contributing to a sort of complexity that I do not normally experience in the process of making purely electronic music. This experience of the physical instrument led me to name the finished pieces after physical vibrations I could recall. I named the resulting album *Transductions*, the term for the

transferal or conversion of one energy form to another, in this case kinetic energy to sound waves.

I undertook a further cull of the recordings to develop the material into a cohesive album. Lawrence English, who runs Room40, an Australian record label, generously offered to release the album, exposing the material to a broader Australian and international audience. The album was released on June 5th, 2020. Unfortunately, due to the COVID-19 pandemic I was unable to present or perform the album live at the time of its release.

Transductions (2020) was released digitally by Room40. See **Practice Outcomes Appendix Audio Example 3** for further details.

Performances 2021

The COVID-19 pandemic caused most live music activities to cease or move online in Sydney in 2020. In early 2021 the NSW Government began relaxing restrictions and even incentivising the public to attend cultural activities in person through a voucher scheme. A number of opportunities for me to perform live arose during this time and I focussed my efforts on developing material that I could perform live.

Vitalise at Good Space, April 15, 2021

The City of Sydney Council and the NSW Government made a disused restaurant in The Rocks area of Sydney, a tourist location situated next to the harbour, available to a collective of artists and event producers. It operated as *Good Space* for several months in early 2021. I was asked to perform at *Vitalise,* a regular event series held there that focussed on presenting performers who use modular synthesisers.

I was interested in continuing to explore complex pitch-based material as I had with the *Transductions* recordings. however, accessing a MIDI-controlled piano for live performance was not possible, and I was also keen to hear how those approaches might work with layered synthesised voices. I began working with a combination of a Korg Minilogue, a small 4-voice analogue polysynth, and a Korg Opsix FM synthesiser with up to 32 voices.

Working with a new CV to MIDI module, an ADDAC 222 (ADDAC System, n.d.), I was able to separately address up to four MIDI channels polyphonically, even shifting the notes for a particular channel up by one or two octaves for each instrument. I found I could develop separate but related patterns of CV and gates from the modular to address each instrument

and then fade each synthesiser's signal in and out using a mixer. Given the complexity of the modular patch itself, I took a relatively simplified approach to the external MIDI instruments by focussing on just two or three parameters to adjust during the performance.

The resulting performance consisted of complex, layered melodies that faded in and out over the top of one another. The timbres intensified over the course of the 20-minute performance, touching upon almost anthemic rave-like tone colours, organised outside of any perceptibly regular timing, and unsupported by the percussive elements usually associated with those sounds.

The performance seemed to be well received by the audience with several people keen to chat about the approach I had used immediately following its conclusion. This performance system extended the complex programmer and wave folder pitch modulator patch components by adding control of polyphonic and multi-timbral sound generation. Incorporating external synthesisers under the control of a modular synthesiser was a seemingly unlikely use of a modular synthesiser but this approach allowed me to focus on the live, improvised creation of musical structure. The experience of preparing and performing reinforced to me the delicate balance between the instrument system and my own performative agency. Much of the work undertaken in preparation was concerned with fine-tuning this balance, delineating the parameters and range of change that intervention should produce without the instrument drifting outside of the territory I wanted to explore.

Steep St Artist Run Initiative, April 24, 2021

I was also invited to perform at Steep St, a Katoomba-based artist-run initiative (ARI), the following week, alongside Sydney-based musicians Alexandra Spence and Megan Alice Clune. I performed with the same system and external MIDI instruments as I did at the *Good Space* event, having become more accustomed to the instruments and system as a whole. I felt more confident and able to explore the possibilities a little more freely, exploring melodic territory that felt dynamic and intuitive as a performer.

The performance seemed to again be well received by the audience. Being in the position of performing with an almost identical approach more than once assisted me in being more confident of my role as a performer and of the instrument's responses to my interventions.

A recorded excerpt of the performance is provided, see **Practice Outcomes Appendix Audio Example 4**.

Warehouse location, Alexandria, Sydney, May 28, 2021

In May, I was asked by a friend to perform at their warehouse space in Alexandria. The timing of the event enabled me to develop the approach significantly, bringing in an extra element in addition to the melodic elements I had worked with previously. I am fascinated by descriptions of Morton Subotnick's 'ghost electronics' approach (Hanson, 2010), where he used recordings of his own voice via an envelope follower in his Buchla instrument to modulate components of the instruments patch via the amplitude of his voice (p. 26). This approach was effectively a form of parameter automation; however, the use of his own voice enables a nuanced and humanised element within an otherwise wholly electronic system. By recording the vocal gestures or 'energy shapes' on to tape, this enabled Subotnick to edit and sequence components of the synthesiser system via tape-editing processes (Hanson, 2010, p. 27).

Subotnick's ghost score approach interested me as a process that enmeshed sound recording into a complex synthesiser system as a control source rather than a sound source. The use of the human voice in this way brought a complex, immediate and embodied element into a highly automated system. It struck me that the ghost score approach might be modified using contemporary Eurorack sampling modules so that the vocal recordings are also edited or sequenced in real time as a component of the synthesiser system itself. This approach would enable these 'energy shapes' to shift fluidly within the broader system while retaining something of their dynamic, humanised and organic origins.

For Subotnick the vocal recordings imparted their shape into control voltage through their amplitude alone, as the pitch of the gestures could not be translated via the Buchla's envelope follower. I was interested in taking a different approach, using a vocoder to allow the recorded voice to impart frequency-specific amplitude information into the synthesiser system. This approach loses some of the flexibility of Subotnick's original ghost score approach in that the voice recordings would no longer be flexibly used to modulate any parameter; instead, the role became essentially limited to the control of a group of bandpass filter frequencies. However, the use of a vocoder would enable the voice gestures to impart a rich and dynamic element to the sounds produced by the synthesiser system.

With this process in mind, I added a 4MS Stereo Triggered Sampler (4ms Stereo Triggered Sampler*,* n.d.) to my modular instrument. I would have liked to also bring the possibility of a vocoder into the modular itself, however, the expense and size of suitable vocoder modules

led me to instead use software to perform this function. I began by recording a series of guttural-sounding vocal noises, I wanted to avoid the eventual vocoded sounds imparting a robotic sound typical of much vocoder use, and I also wanted to avoid recognisably human or speech-like outcomes. I hoped that these sounds would allow dynamic and complex elements to exist within the system as energetic expressions.

Operating in mono mode, the 4MS sampler module enabled the samples to be selected and played back via two separate playback components with dedicated audio outputs. Each allows the sample pitch and position to be adjusted manually via dedicated knobs and CV. I incorporated the sampler module into the system I had used for the previous two performances, deriving timing information and CV sources from the *complex programmer system component* and *wave-shaped modulation system component.* The two audio signals from the sampler were then brought to my laptop via an audio interface, forming modulator sources for two Ableton Live vocoders.

The carrier sources were derived from oscillators in my modular synthesiser, using two pairs of oscillators configured to frequency modulate each other, producing bright and noisy timbres. Each pair of oscillators was also pitch modulated by an envelope, the timing of which was derived from the same sources as the sample module, to produce dramatic, percussive timbres in sync with the spectral information provided by the samplers. Once vocoded, the sampler and oscillator sources combined to form complex sound sources that could be adjusted via multiple parameters, either manually or via CV. By treating each of the two vocoders as distinct sound sources I was able to fade each in and out of the mix, and even use headphones to adjust each source before making them audible to the audience.

The resulting system was incredibly complex to perform with multiple sound sources from the two external synthesisers, the two vocoders, and the layered and interrelated parameters governing their behaviour. As a result, I found that I needed to pre-plan the performance in some detail, effectively delimiting the improvised elements so that the process of performing would remain manageable. I was very pleased with the eventual performance, and it was well received. However, I did come away from the experience determined to simplify my approach and free myself up to allow a more improvised approach to performing. While the system enabled a highly improvised approach, both through the control of the external synthesisers and the samples and synthesis elements combined through the vocoder, I found that I could not attend to these elements simultaneously with any in-depth focus. My attention was spread across all the elements of the interconnected systems and equipment in an effort to maintain an overview of the performance as a whole, mixing elements and guiding the systems to evoke an overarching structure.

A recorded excerpt of the performance is provided, see **Practice Outcomes Appendix Audio Example 5**.

Performances 2022

In the final year of this research, I was keen to explore creating music that featured repeatable rhythmic elements more closely aligned with electronic dance music. This was partly due to having worked with largely abstract forms for many years, whilst enjoying and listening to music at the more experimental end of techno, and I felt ready to shift back towards more structured and repeatable forms. I also wanted to include within this research processes and experiences of applying some of the systematised approaches I had worked with to more structured forms of music to illustrate their potential and relevance in a different context.

Mono-Poly-April, Liquid Architecture, Music Market, Collingwood Yards, April 7, 2022

In early 2022 the opportunity arose to perform for Melbourne sonic arts organisation Liquid Architecture at their event *Mono-Poly-April*, and I decided to use this opportunity to explore a departure towards rhythmic and repetitive material. Working with an Elektron Rytm drum machine (Analog Rytm MKII | Elektron, n.d.) to produce percussive sounds, the modular synthesiser was able to trigger each sound via a dedicated trigger to MIDI interface (Ladik, n.d.), in combination with a CV to MIDI CC (Control Change) interface (A-192, n.d.) that allowed specific parameters of the drum machine to be modulated. While the Rytm is capable of producing up to eight voices simultaneously, I focussed for the most part upon just four voices for each rhythmic pattern.

Using variations of the *Semi Synced LFO system component,* described in detail later in this chapter, I was able to create complex rhythms that seem to slide in and out of sync. The Rytm drum machine was used to provide a MIDI sync signal converted by a MIDI input module to produce regular 16th note timing that formed a master clock signal for the modular to base its timing signals on. The Rytm was also used to produce a trigger signal every four bars so that the entire system could be reset at a regular interval. This enabled the otherwise disjointed semi-synchronised trigger signals to be reset simultaneously every four bars to create a regular repetition of the pattern generated by the modular synthesiser.

Using variations of the *wave shaped pitch modulation system component* described in detail later in this chapter, and syncing the Pingable Envelope Generator to the LFO generated

trigger signals, I was able to produce misshapen and unpredictable CV signals that were then converted to MIDI CC signals. These MIDI CC signals were then applied to various parameters of the Rytm such as filter cut-off frequency, and repeated in line with the overall pattern. The interaction of the triggers and the MIDI CC parameters seemed to form a rich intricacy based upon the complex relationships between the components.

Each pattern was recorded as MIDI data by the Rytm as a four bar loop and associated with a particular ‘drum kit’ on the Rytm so that each pattern had a particular set of sounds associated with it. This enabled a pattern to be composed and then captured by the Rytm so that other patterns could be generated and experimented with using the modular synthesiser.

For the performance for Liquid Architecture, I prepared four of these patterns with associated sets of sounds using the Rytm’s analog synthesis engines. I utilised the Rytm’s dedicated outputs so that each sound had its own output, enabling the elements to be mixed together using a mixing desk and taking advantage of a four-band equaliser for each channel, alongside dedicated effect sends to reverb and delay effects. I mixed each element in and out to slowly build a broader structure to the otherwise repeating patterns.

Alongside the rhythmic patterns I also improvised melodic elements using the modular synthesiser to control two external synthesisers via MIDI, a Sequential Take 5 Compact Poly Synth (Sequential, n.d.) and a Korg Opsix FM synthesiser. Utilising the *wavefolded pitch modulator system component* kept in sync with the patterns using the sync signals from the Rytm I was able to compose and mix melodic patterns in addition to the rhythmic material on the fly.

This approach to creating rhythmic patterns that were then recorded as MIDI situated the modular synthesiser even more firmly as a compositional tool than previous approaches I had undertaken. With this approach, I was not only separating the sound generation from the musical event generation, but also situating the modular synthesiser as a studio tool that would not necessarily be required for a live performance. I found that this approach enabled me to compose complex rhythms, different and more interesting than I felt I could create through step-based or manual performance. As the act of composition was undertaken by designing the system that would generate the patterns, I found that I was able to conceptualise various interactions and relationships within the system based on phasing, Boolean logic or complex modulation. There would be a degree to which the complexity of the system overwhelmed my ability to preconceive the system, and as I built each patch I

would shift from the original concepts I sought to investigate into unknown territory, where my role shifted to trial and error-based experimentation with the system.

I found this approach, where I was able to utilise a complex system to create unexpected but desired results and then capture these as static patterns, to be very attractive. The process relieved the pressure of recreating a system for live performance, allowing me to experiment more freely and build the recorded MIDI into larger compositions through more traditional approaches to editing MIDI and mixing audio through a DAW.

A recording of the performance is provided, see **Practice Outcomes Appendix Audio Example 6**.

After Dark, Sydney Living Museums, Hyde Park Barracks, June 2022

I was invited to perform at an *After Dark* event at Hyde Park Barracks, a historically significant sandstone building constructed in 1819. The performance occurred in the Hammock Room, an example of the soldier's sleeping quarters, hung with dozens of hammocks open to the public to recline in. The event organisers had planned for a long-form performance of one hour and 45 minutes, and a four-channel surround sound system was installed in the room.

Due to the long form nature of the concert, and the opportunity for the audience to relax in hammocks, I decided to present an evolved version of the approach I had utilised in 2021, focussing upon melodic elements produced by MIDI-controlled hardware synthesisers, with the modular synthesiser producing MIDI data through real-time improvisation and the *wavefolded pitch modulation system component*, in combination with the *complex programmer system component*. In addition, the modular synthesiser also produced MIDI signals that were used to pan audio from the two synthesisers around the space.

To approach the quadraphonic panning I used a K-Mix Audio Interface Digital Mixer & Control Surface (Keith McMillan Instruments, n.d.) digital mixer, which is capable of mixing for surround, and can be MIDI controlled. I utilised the complex CV signals used to produce pitch information to also control the pan position of the synthesisers. I swapped the signals so the pitch source for each synthesiser controlled the pan position of the other. This approach avoided a direct correlation between the pitch and pan position of a particular synthesiser, which I imagined may become somewhat tiresome over the length of the performance.

This approach to addressing the quadraphonic arrangement of speakers added an additional layer of variation resulting from the complex system and my improvised interactions with the system. As the surround panning was derived from signals that were also utilised for pitch information, the addition of this layer did not necessarily create additional complexity for me as a performer. However, the addition of surround sound did create a richer sensory experience of the space that likely influenced me in the process of improvising.

Due to the length of the performance the audience moved in and out of the space, with some choosing to lay in a hammock for long periods of time. As the audience was not fixed, nor was any member of the audience exposed to the entire performance, I chose to focus on slow but continuously evolving motifs to create what I hoped would be interesting material regardless of the length of time the audience member spent. The results were somewhat sad sounding, slow, rambling melodic clusters that repeated in part but morphed over time.

Many audience members stayed for long periods, possibly asleep, or at least relaxing with their eyes closed. I received very positive feedback from both the audience and staff from the Hyde Park Barracks, who suggested the music perfectly matched the space and its troubled colonial history.

A recorded excerpt of the performance is provided, see **Practice Outcomes Appendix Audio Example 7**.

Practice Outcomes Summary

The practice outcomes detailed above illustrate my interest in how a modular instrument can be explicitly used to organise and construct musical structure. In addition, they provide evidence of my fascination with the possibilities for creating interesting timbres when using a modular, and the way that these timbres can be intricately linked and entwined with elements that are focussed on generating musical structure. In retrospect, I think that by separating out the sound-making aspect of a modular synthesiser I was reducing the complexity of the system and experience so as to better understand the modular synthesiser’s nature as an instrument that can create musical structure.

System Component Descriptions

Through the experience of conducting this research project and the incorporation of my creative practice through reflection, I have become aware that I reuse particular aspects of a patch. In some cases these *system components* have developed a distinct identity in my conceptualisation of the systems I compose. This approach assists in managing the complexity I encounter when conceiving of a patch, as, since I know these system components well having patched them many times, I can focus my attention upon the new ideas and elements I intend to explore. This approach to the refinement and reuse of sub-patches is reflected in the practice of several of the research participants as outlined in Chapter 5.

In this section I offer descriptions of the system components used in my work. As some of the language and terms are not in common usage, I set out below how the following terminology is used within these descriptions.

Module: a single hardware device within the modular system. Specific modules are referenced in the text with links to the manufacturer's documentation.

Patch: the total configuration of modules and interconnections that entail a complete modular performance system. A patch may be modified during performance.

Sub-patch: a combination of modules and their interconnections that perform a limited function within the overall patch.

System component: a conceptualisation of a sub-patch in terms of its musical application.

The following system components have been developed and reused through the creative practice activities recounted above. The inclusion of their description outside of the context of a particular patch or performance acknowledges the modular nature of their use.

Complex Programmer (A-152 and Complex, Repeatable, Changes)

I originally developed this approach while performing and recording in the duo Nadir. A key component of this approach is the Doepfer A-152 (A-152 Voltage Addressed Switch, n.d.), one of the earliest modules I bought, and likely one of the only I have held onto over the past ten years. The A-152 allows eight stages, each a combination of a switch, a track and hold circuit, and a digital output or gate to be addressed together, using either a CV source or

sequentially using a gate or trigger source. The configuration of the module allows for a range of operations to be performed depending upon how the module is patched, including management of polyphonic voices, an analog shift register or complex router.

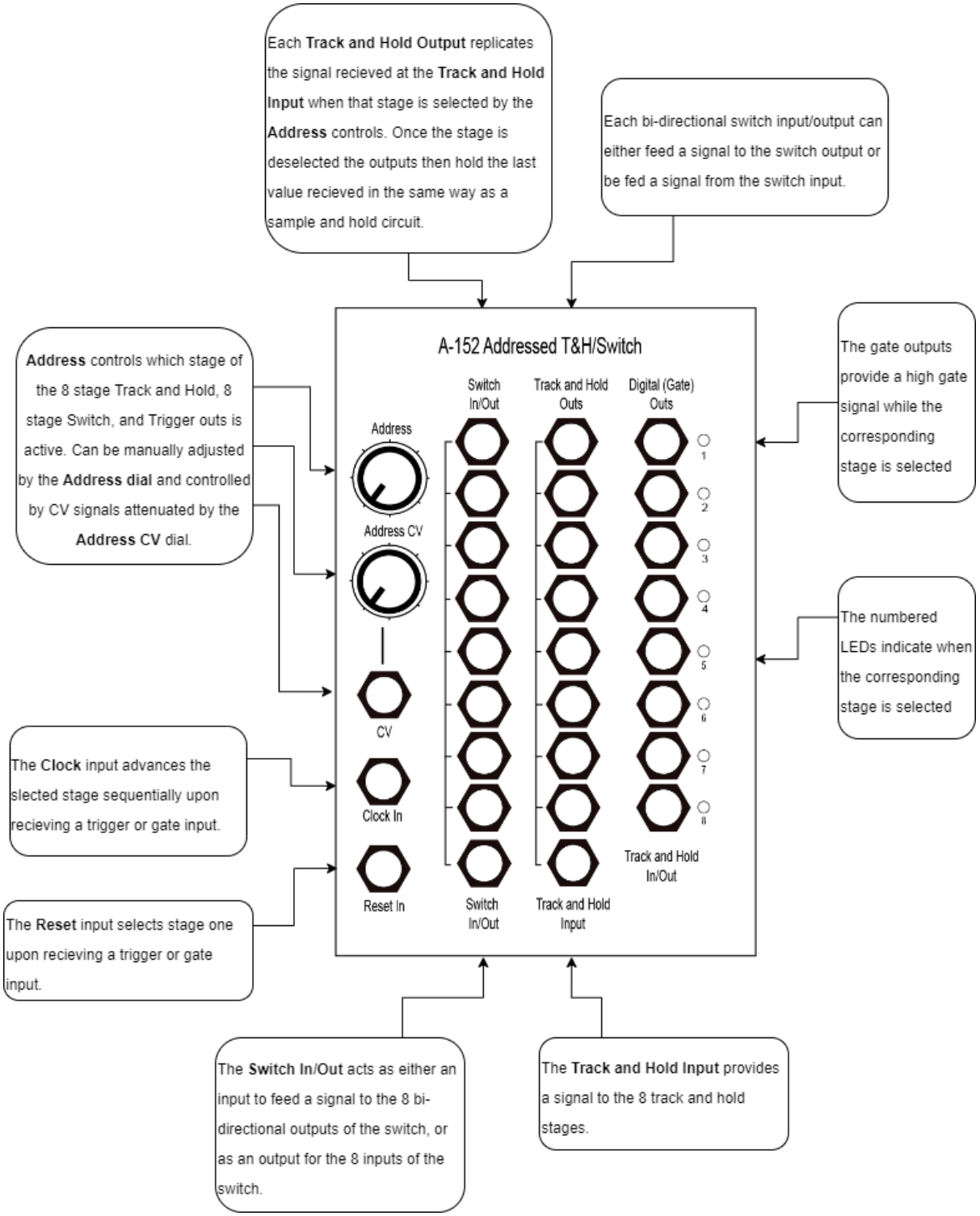
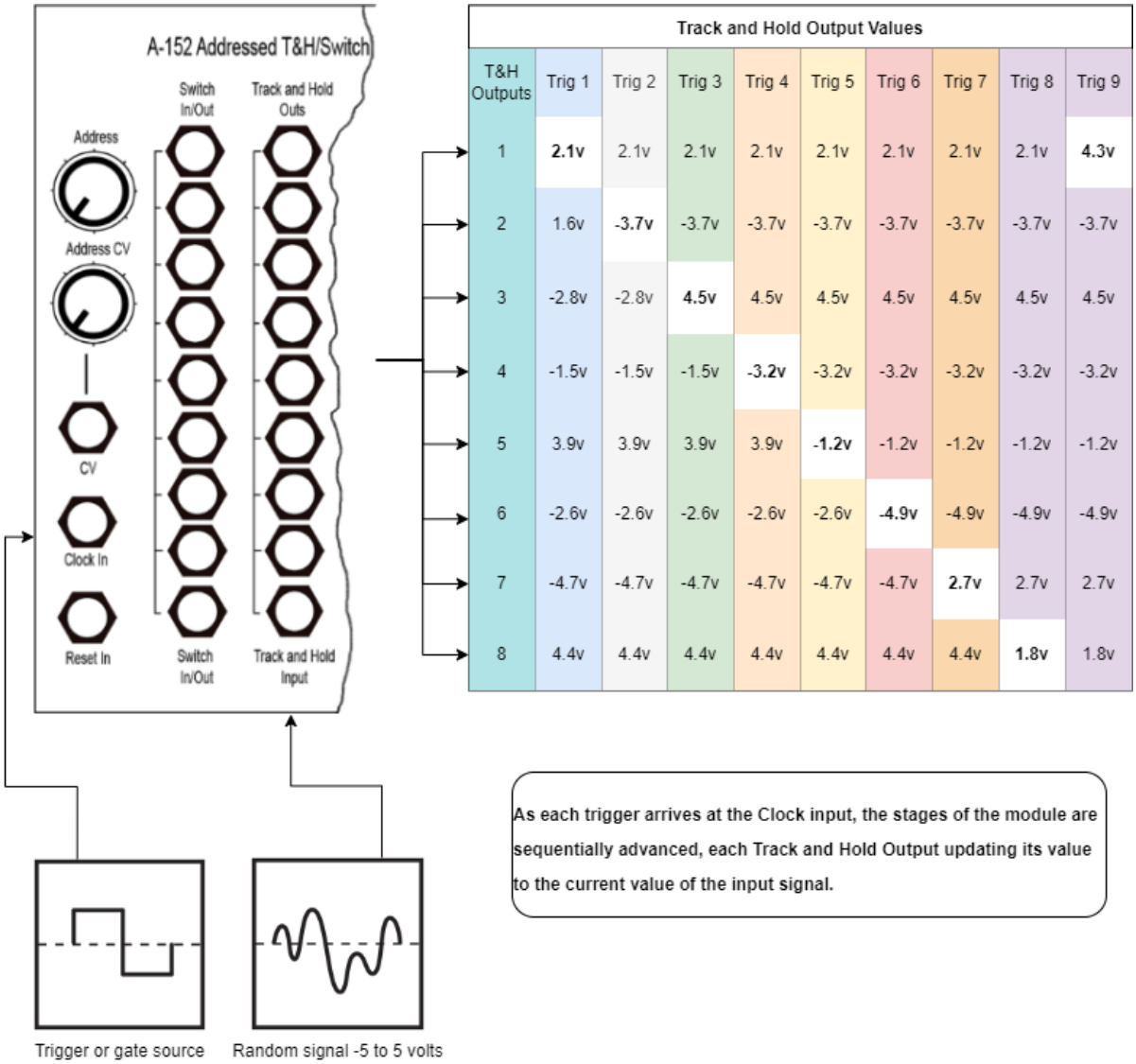


Figure 2. Overview of Doepfer A-152 Addresses Track and Hold Switch

In the context of Nadir I was interested in being able to instigate indeterminate changes to multiple parameters throughout a patch. For this purpose I fed the A-152s track and hold input with a noise source and then patched the 8 CV signal outputs to various parameters throughout the patch, often utilising a stackable cable or signal splitter to allow an output to address multiple parameters simultaneously. The parameters controlled by the A-152 ranged from timbre-forming elements such as oscillator pitch, frequency modulation, and relative amplitude of various audio rate signals, to include structural elements such as the speed and shape of amplitude envelopes and clock divisions. The stages would then be selected sequentially by a trigger or gate source, with the source usually derived from an end-of-cycle trigger from an envelope applied to amplitude, so that after a voice had sounded the next voice would change in some dimension. The components of the patch responsible for the timing of the envelope triggers were usually modulated by the A-152 so that a level of chaotic feedback was in operation.



Track and Hold Output Values

T&H Outputs	Trig 1	Trig 2	Trig 3	Trig 4	Trig 5	Trig 6	Trig 7	Trig 8	Trig 9
1	**2.1v**	2.1v	2.1v	2.1v	2.1v	2.1v	2.1v	2.1v	**4.3v**
2	1.6v	**-3.7v**	-3.7v	-3.7v	-3.7v	-3.7v	-3.7v	-3.7v	-3.7v
3	-2.8v	-2.8v	**4.5v**	4.5v	4.5v	4.5v	4.5v	4.5v	4.5v
4	-1.5v	-1.5v	-1.5v	**-3.2v**	-3.2v	-3.2v	-3.2v	-3.2v	-3.2v
5	3.9v	3.9v	3.9v	3.9v	**-1.2v**	-1.2v	-1.2v	-1.2v	-1.2v
6	-2.6v	-2.6v	-2.6v	-2.6v	-2.6v	**-4.9v**	-4.9v	-4.9v	-4.9v
7	-4.7v	-4.7v	-4.7v	-4.7v	-4.7v	-4.7v	**2.7v**	2.7v	2.7v
8	4.4v	4.4v	4.4v	4.4v	4.4v	4.4v	4.4v	**1.8v**	1.8v

Figure 3. Example outputs from Doepfer A-152 with random signal input

In the context of Nadir, this approach forced me to be on my toes, responding to the changes as they occurred, working either with or against them. The range of the noise source feeding the track and hold stages meant that changes were sometimes so dramatic that I would lose track of what had changed and be unable to bring the instrument back to a point where I felt able to respond or intervene effectively. I began to attenuate the signal from the A-152 to within particular parameters so that the range of changes was less drastic, making the process of improvising with the system somewhat easier and less unpredictable.

In the context of Nadir where there was another performer, and an intent to work with a multilayered concept of noise, the application of random voltage made sense. As I shifted to the General MIDI and acoustic piano projects, I found that the use of random voltages was counterproductive to the process of learning the system and confidently improvising with it.

On one hand, I wanted to retain the unpredictability of a central control source impacting multiple parameters, and on the other, I wanted to be able to return to particular structures and distort them in a way that was nuanced and controllable. I then developed a technique using a 4MS Pingable Envelope Generator (4ms PEG, n.d.) (PEG) as the source of the A-152 track and hold input.

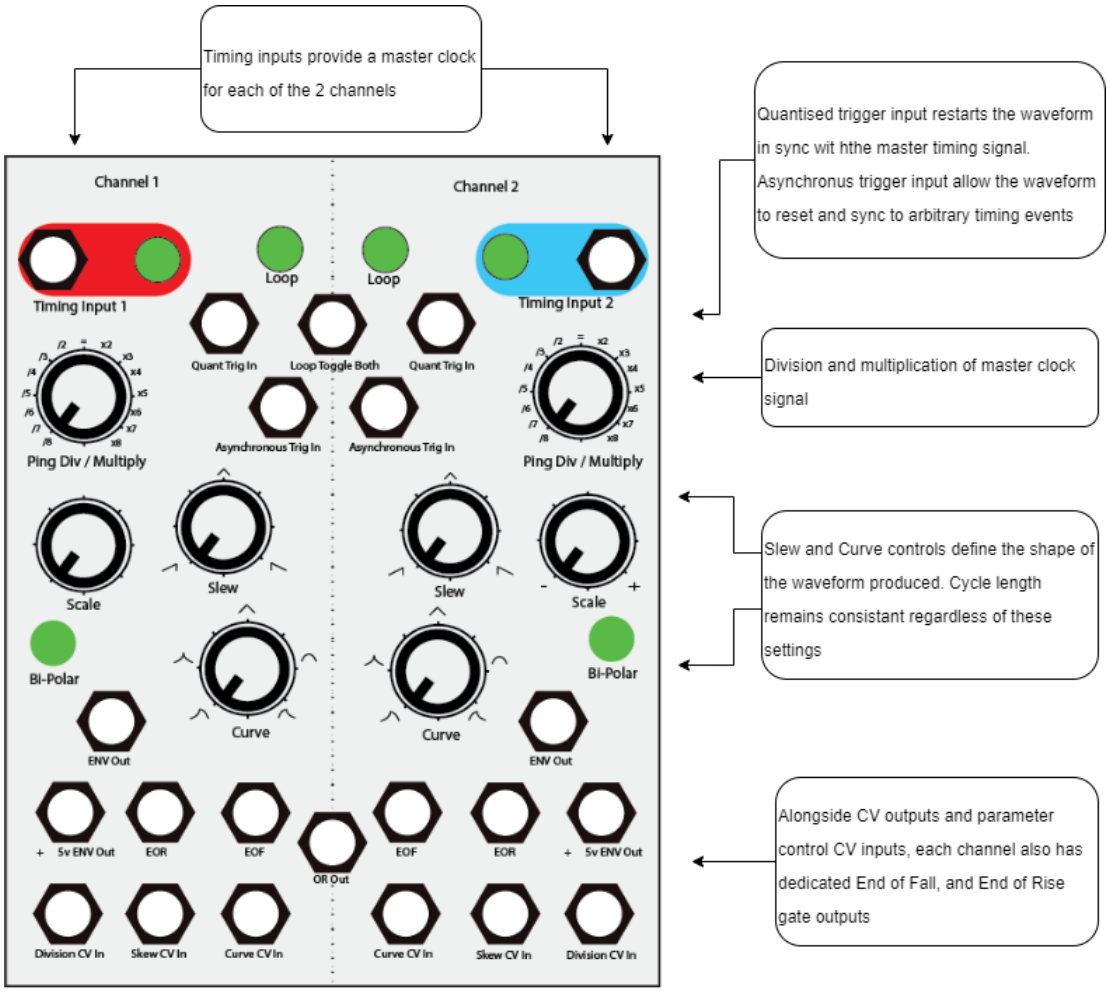


Figure 4. Overview of 4MS Pingable Envelope Generator

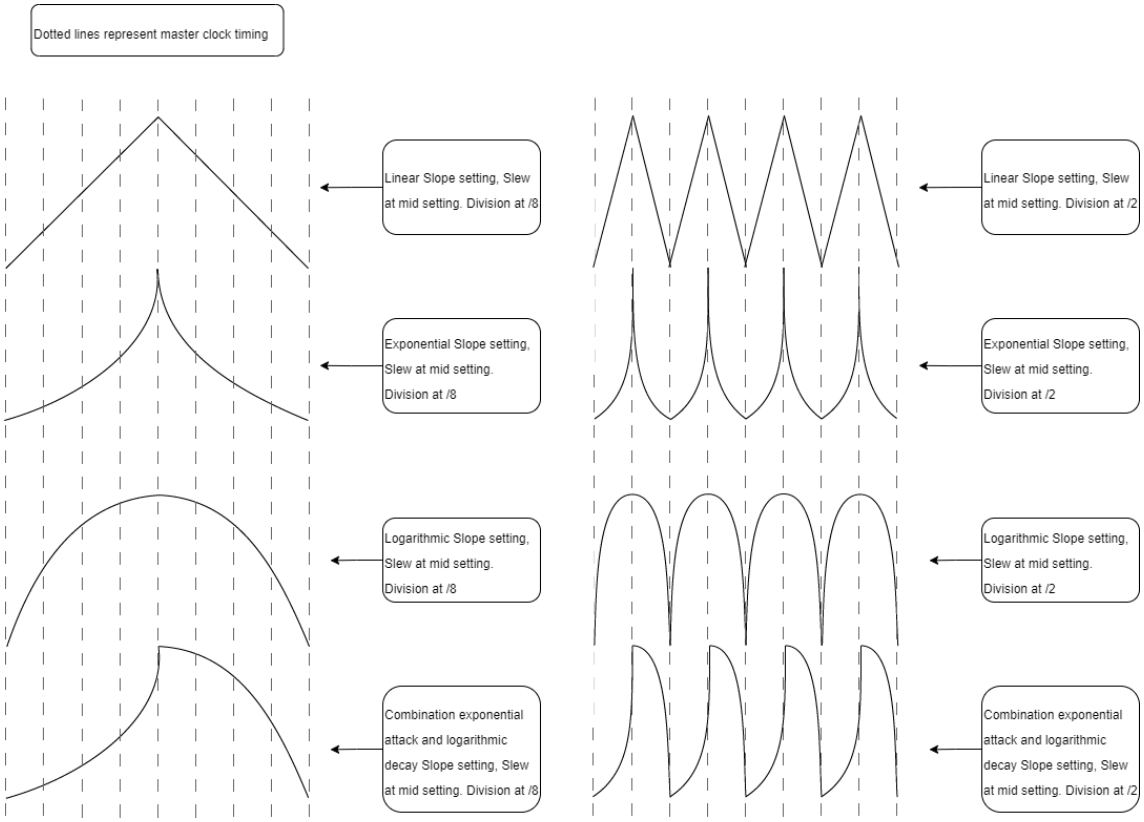
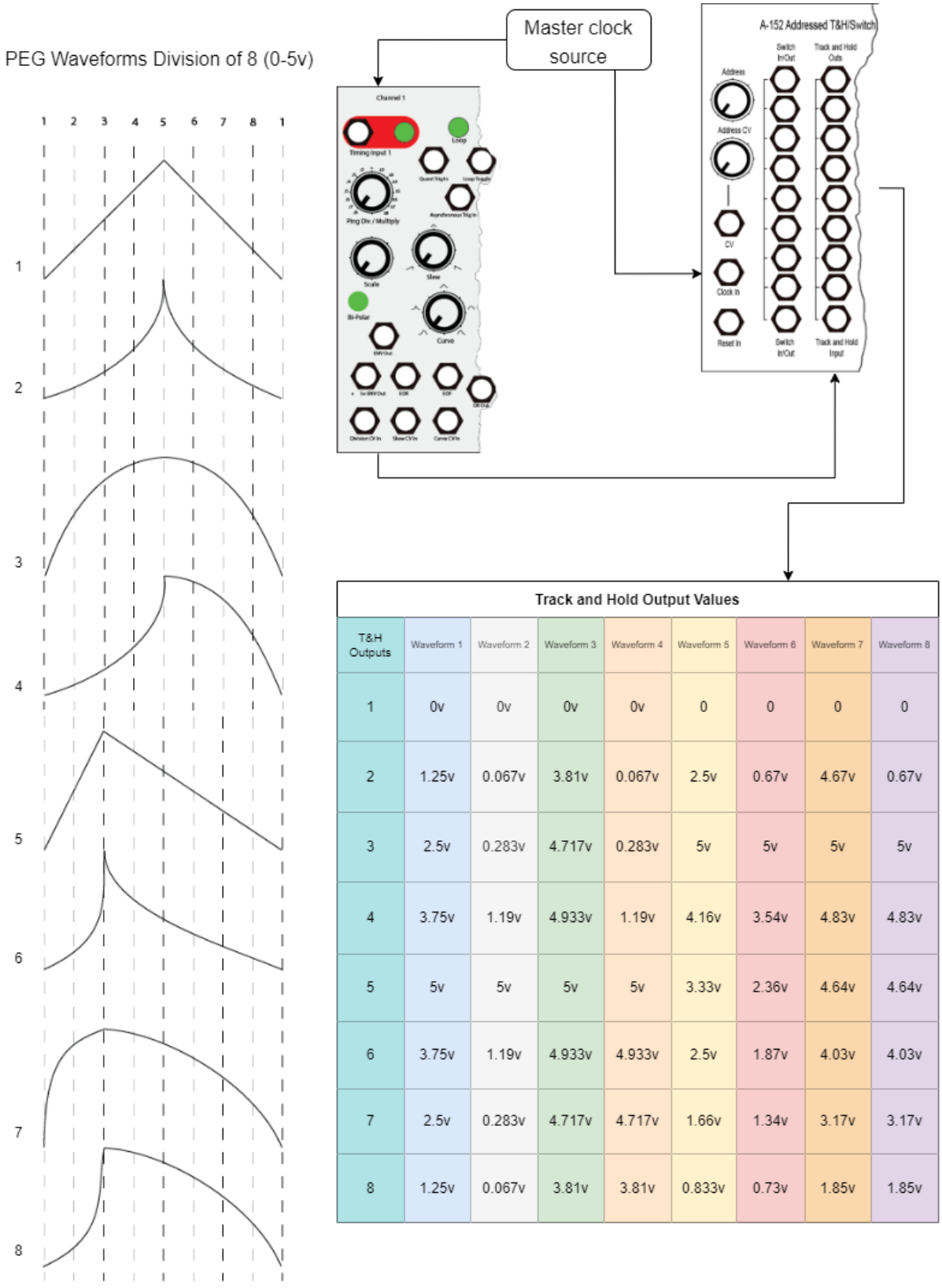


Figure 5 Example Pingable Envelope Outputs

The 4MS PEG envelope generator uses timing information from trigger and gate sources to adjust the length of its envelopes. This allows for adjustments to be made to the shape of the envelope without affecting the overall duration. By syncing the timing source with the A-152 stage selection, the PEG's envelopes can be locked to the cycle of the A-152 stages. The PEG's length can also be divided to create a range of relationships between the two modules, allowing for envelopes to complete in the exact time the A-152 cycles or to repeat within various phased relationships causing the two modules to fall out of sync and eventually return into sync after a specific number of timing triggers.



Track and Hold Output Values

T&H Outputs	Waveform 1	Waveform 2	Waveform 3	Waveform 4	Waveform 5	Waveform 6	Waveform 7	Waveform 8
1	0v	0v	0v	0v	0	0	0	0
2	1.25v	0.067v	3.81v	0.067v	2.5v	0.67v	4.67v	0.67v
3	2.5v	0.283v	4.717v	0.283v	5v	5v	5v	5v
4	3.75v	1.19v	4.933v	1.19v	4.16v	3.54v	4.83v	4.83v
5	5v	5v	5v	5v	3.33v	2.36v	4.64v	4.64v
6	3.75v	1.19v	4.933v	4.933v	2.5v	1.87v	4.03v	4.03v
7	2.5v	0.283v	4.717v	4.717v	1.66v	1.34v	3.17v	3.17v
8	1.25v	0.067v	3.81v	3.81v	0.833v	0.73v	1.85v	1.85v

Figure 6. 4MS Pingable Envelope Generator synced with Doepfer A-152

The advantage of this approach is that by changing the shape of the PEG's envelope I can shift the relative levels of the A-152's CV outputs, resulting in unpredictable changes across a range of parameters. Instead of these changes being unrepeatable as they were when a noise source fed the A-152, I am able to return to a particular configuration, approximately at least, by adjusting the envelope back to the same settings. If the PEG and the A-152 are in sync then I can also cycle them both at high speed so that any changes occur almost simultaneously across the A-152's parameters. As long as the two modules are locked to the same clock source the output voltages will not vary from cycle to cycle until I adjust the envelope's shape.

One drawback of this approach in comparison to the noise source feeding the A-152's track and hold input is that an envelope follows a linear path, rising from zero to its peak and then returning, according to whatever settings have been applied to its shape. This caused the relative levels of the A-152's outputs to be somewhat predictable. I was interested in making this aspect more complex, but without losing the ability to return to a particular configuration. To resolve this, I inserted an Intellijel µFold ii wavefolder (Intellijel Eurorack Synths, n.d.) between the output of the envelope and the A-152's track and hold input. A wavefolder mirrors a waveform back towards its zero crossing at a definable threshold. In the case of the µFold ii it is also possible to adjust the symmetry of the wavefolding, essentially a voltage offset applied to the input that pushes the waveform closer to either the top or bottom threshold, and also adjust the number of folds, which applies amplification to the signal causing it to fold upon itself multiple times.

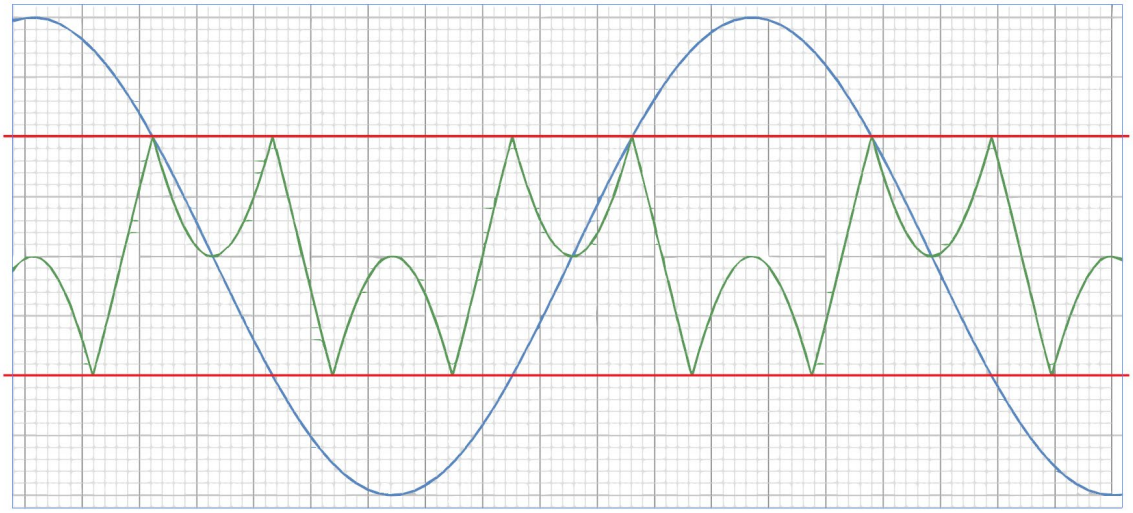


Figure 7. Example of wavefolder effect upon waveforms. Blue represents the original sine wave, green is the folded wave, and red is the threshold where the waveform is folded back towards the zero crossing.

The wavefolder creates a more complex and unpredictable version of the envelope's CV output that is entirely consistent, retaining the repeatability of the synced envelope generator. As a result, the track and hold outputs of the A-152 no longer followed a linear curve from low to high and back to low again, instead exhibiting multiple peaks and troughs throughout the range of outputs. Slight changes to the PEG's envelope's shape resulted in drastic changes to the wavefolder output. By adjusting only one or two parameters on the PEG I was able to dramatically shift the entire structure of pitch, event timing, and MIDI velocity and still return to a particular motif or gradually distort the musical structure.

I use the term *complex programmer* to describe this system component as it acts upon key components of the entire patch, behaving much like a preset manager in a more traditional, modern synthesiser, or the Serge Sequencer/Programmers (Wizardry, n.d.). However, instead of being limited to a set number of eight or 16 stages, each defined by the musician, it allows continual adjustment between a seemingly limitless number of configurations at the cost of the musician not being able to define the configurations. The *complex programmer* emphasises a process of discovery and encourages me to work collaboratively with the instrument while still allowing a knowledge of the instrument to be developed, which supports deliberate, improvised interventions into the instrument.

Wavefolded Pitch Modulation

I also adapted the use of wavefolded PEG envelopes to form the source for pitch information in both the General MIDI and piano works I created. In these instances, I used an Intellijel Planar (Planar2, n.d.) joystick router to blend between two PEG envelope VC sources, and the same two sources after each had passed through a waveshaper. This approach enabled me to control the level of complexity in the pitch information being sent to the external MIDI instrument. By using two separate envelopes I was able to combine slower movements with faster repetitions to create complex arpeggio-like structures. The Planar's joystick allowed me to modify the relative levels of each CV source with nuanced control before sending the eventual signal on to a Toppobrillo Quantimator (Toppobrillo Quantimator, n.d.) pitch quantiser.

Rhythm and Timing Sources

The system components described above relied upon a further system component dedicated to the generation of timing information to govern when notes would occur. I found that this component of the broader instrument system was the key to obtaining reliably satisfying

results, which were consistently more challenging to design. Over the course of the research project, I have worked with a range of rhythm and timing techniques. The following have stood out as the most successful and were utilised in specific creative practice outcomes.

Unsynced LFOs

For the general MIDI and piano works, I wanted to move away from the strict grid structures associated with popular electronic music. However, I also wanted to avoid an outcome that sounded entirely randomised and jarring for the listener as, to my ears, this would impart an excessively complex and inaccessible structure typical of the musical avant-garde. Neither was I intending to simulate a human performer; instead, I hoped to find an approach that was simultaneously dynamic, synergistic, complex, and somewhat decodable for a listener.

Using a Toppobrillo Sport Modulator (Sport Modulator 2, n.d.) in cycle mode as a pair of LFOs, each end of the cycle trigger was then combined via a Doepfer A-166 Logic Gate (A-166, n.d.). As the two sections of the Sport Modulator were not synced but cycling in regular periods, the AND and OR outputs of the logic gate would then produce erratic yet perceptibly related patterns of gate signals. These would then be further processed by a 4MS Quad Clock Distributer, which would calculate the periodic cycles and produce clusters of triggers at regular divisions or multiples before recalculating in response to the ever-changing logic gate signals. This created further regularity, imparting a somewhat machinic precision to the otherwise chaotic array of trigger signals

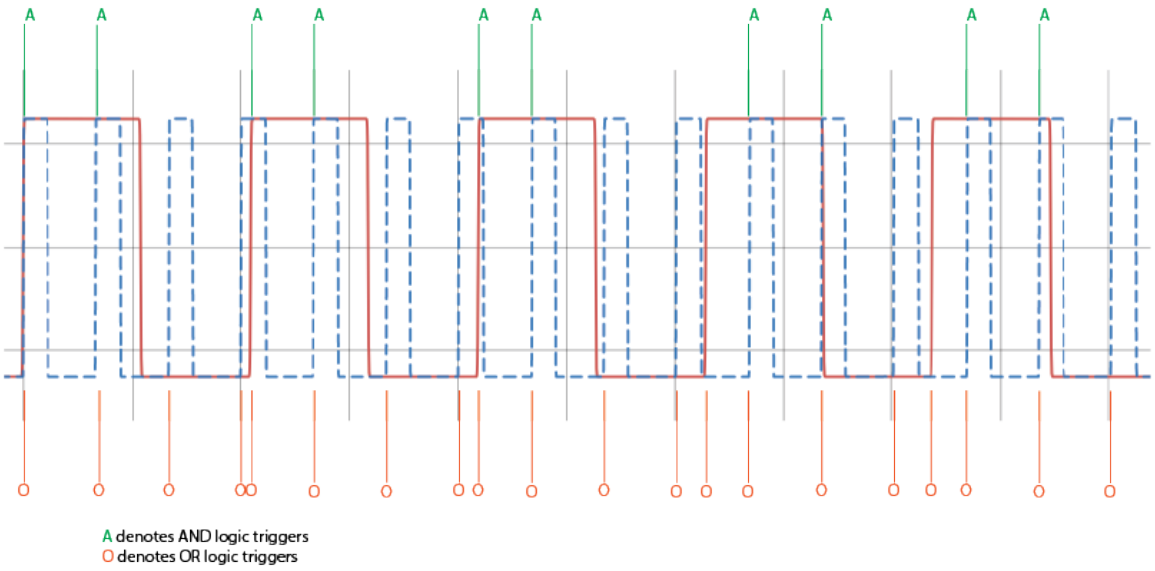


Figure 8. Overview of unsynced gate generation

The resulting triggers were applied to the speed of the envelopes used to produce the *pitch modulation* system component and the envelopes used to feed the Doepfer A-152 in the *complex programmer* system component. MIDI note-on triggers were derived from combinations of the logic gate outputs and clock dividers processed through a switch or further logic gates.

This approach was very responsive to improvised interventions to the timing of the two Sport Modulator LFOs. Small adjustments produce wild variations, speeding up or slowing down the entire musical structure. Once again, this approach provides a sense of performable compositional design at the meso scale.

Semi-Synced LFOs

For the live performances in 2021 I was interested in moving towards structures that had a degree of regularity, and even a definable tempo. However, I still wanted to avoid a grid-like structure or strict timing quantisation. Instead of the Sport Modulator as the main source of timing information, I employed two LFO sources that could be reset by an external trigger: a Doepfer A-147 LFO (A-147, n.d.), and a Malekko Richter Oscillator II (Richter Oscillator II, 2015) in LFO mode. Using square wave outputs from each LFO provided a source of gate signals. Each of these LFO’s could run at odd timings, and even have their speed modulated by external sources, but by applying regular trigger signals to their reset or sync input, the two sources could be brought into syncopated and repeating patterns.

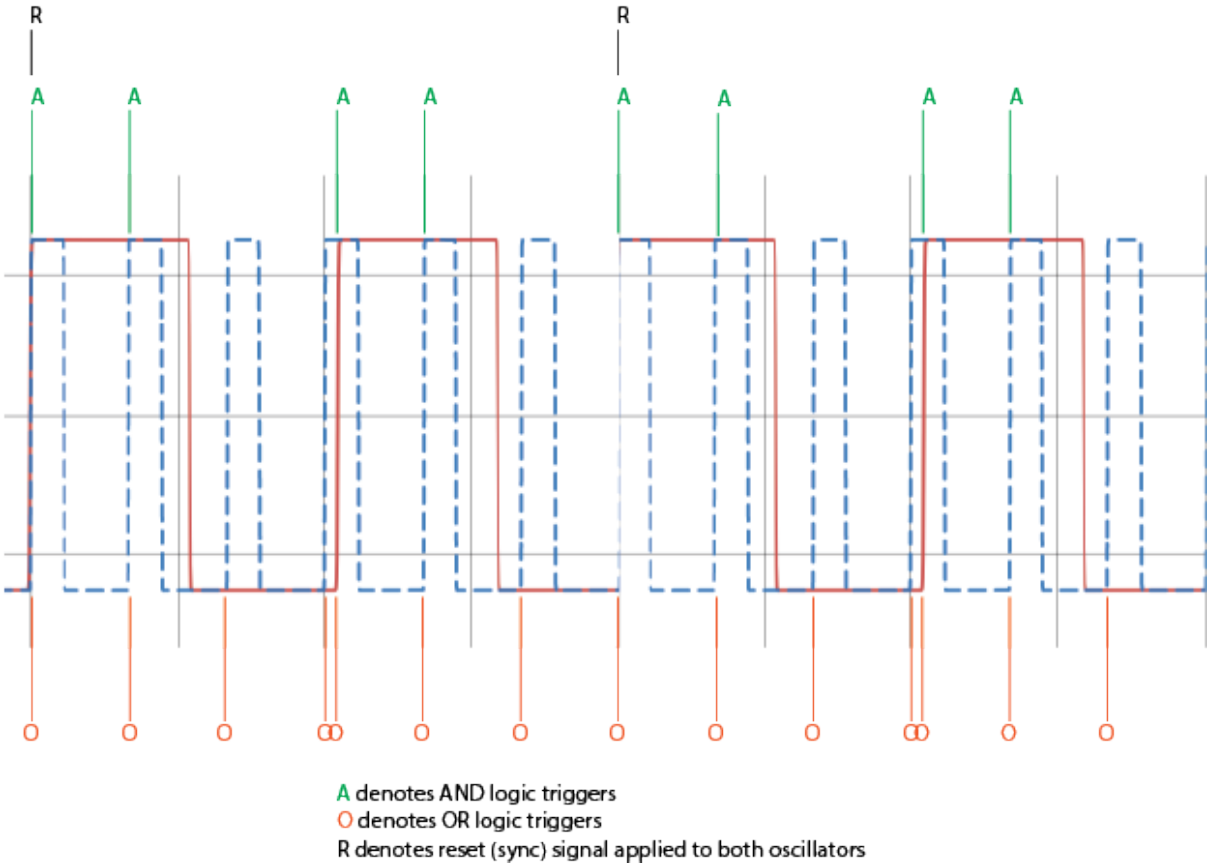


Figure 9. Example of synced triggers as applied to LFO reset / sync input

The trigger signals applied to the reset inputs were derived from clock dividers that were in turn fed by a regular MIDI clock timing signal at a defined BPM from an external sequencing device. The complexity of the relationship between the two LFO timing sources could be increased by resetting each at separate divisions of the BPM, or even using odd numbers such as a division of 5 on one LFO and a division of 7 on the other, creating long, phase-shifted cyclical relationships.

As an extension of this approach, I also applied slowly clocked Euclidian patterns as resets for the two LFOs using a Shakmat Knight's Gallop (Shakmat Modular — Knight's Gallop, n.d.) Euclidean clock generator. Euclidean rhythm generators have become a common sight in modular synthesisers, with a range of manufacturers offering designs dedicated to or capable of producing clock signals based on the Euclidean algorithm. Known for producing complex rhythms that are structurally similar to traditional music from a range of cultures (Toussaint, 2005), when clocked at a slower rate to produce changes, such as resets to clock dividers, the Euclidean clock generator creates an effect that seems to my ears to

sound natural and logical, while also unpredictable and complex in comparison to the usual changes occurring in multiples of four bars in popular electronic music.

In the modular context, the Euclidean algorithm allocates a definable number of trigger events across a definable number of intervals as evenly as possible. In the case of the first variable not being divisible by the second, the resulting pattern will be an uneven allocation of trigger events. While the use of odd divisions for clock dividers for reset signals as described above results in complex-sounding relationships between the two LFOs, the use instead of Euclidean triggers added further complexity to the relationships of the LFOs due to the uneven nature of the Euclidean patterns. The period between each LFO's reset would vary independently as a result. The Knight's Gallop itself could also be reset at regular intervals by a clock divider so that the entire complex pattern would repeat at a regular timing.

Gates as Modulators of Clock Dividers

Another approach I have experimented with for the generation of rhythmic elements is the use of gate signals to modulate the division or multiplication of clock dividers. By applying a gate signal from one clock divider to the CV modulation input of another clock divider, I could temporarily speed up or slow down a clock signal. The gate signal could also be attenuated or inverted so that the exact timing change could be precisely adjusted. If the modulating clock divider was working to an odd division of the same clock source as the affected clock divider, this would result in complex phase-shifting patterns.

Combinations of gates from separate clock dividers via a mixer built upon this complexity such that when the two modulating clock dividers produced a trigger at the same time, this would result in a third level of CV derived from the addition of the separate attenuated gate signals. By using a common trigger signal to reset all three clock dividers, the entire complex pattern could again cycle at a regular interval.

The use of unsynced and semi-synced LFOs combined with Boolean logic, along with using gates as modulators of clock-dividers as the basis of rhythm and timing source system components, has provided both a sense of control and an opportunity for the generation of a variety of material that have both satisfied and influenced my creative goals. This ability for real-time composition and a process of discovery and co-creation are characteristics of the three system components described in this section, which have evolved with my practice over the course of this research.

Reflective Practice Insights and Discussion

To further explore my evolving practice, the following describe aspects of my experiences of using a modular synthesiser that have stood out as being unique or significant components of the experience, and also shed light on the broader musical significance of modular approaches to electronic music.

Creative Constraints

Given my previous experiences of using a computer, and in particular, the graphic programming tool Reaktor to build instruments and perform, the shift to using a modular synthesiser imposed a range of limitations upon the possibilities I felt able to explore. The limitation of the number of modules in the instrument, constrained by both the physical limits of the case itself and the limits of my own finances, meant that the range of components available was substantially limited in comparison to the software environment. If I were to decide that a particular module was necessary to explore certain possibilities then I would likely need to sell a module, buy the new module and wait for it to arrive in the mail, often shipped from the United States. This process could take weeks or possibly months, whereas the equivalent process using software would take seconds. This impacted upon my approach significantly; rather than quickly shifting my approach or trying out several approaches as I might in a software environment, I instead found that I needed to spend time on a problem and compromise my own intentions to find a way forward.

The process and outcomes I would eventually reach with the modular synthesiser were often more than just a compromise of my own intentions, and could be better described as a significant redirection. These redirections might begin as a workaround solution or compromise but would often open up new, previously unconsidered possibilities that would replace the original idea being pursued.

The possibilities for a module being used in multiple distinct ways is one avenue that may offer workaround solutions. Some modules are purposefully designed to be flexible in the function they may perform, such as multi-function digital modules or analog designs inspired by Tcherepnin’s concept of patch programmability (Scott, 2016), while other modules might simply be creatively ‘misused’ to produce the desired function.

The use of a limited number of modules also leads to some modules being used for more than one purpose at a time. A simple example of this in my own practice is the use of an LFO module with multiple waveform outputs available concurrently, such as square, sine,

and sawtooth waveforms. In a software context, I may have been more likely to simply add another LFO to the instrument, however, given the limits of a physical modular instrument I will often use these multiple outputs from one LFO to address a range of parameters within a patch. As the LFO module has but a single control for the rate of all the waveforms it offers, multiple aspects of the patch become interdependent and cannot be modified discretely. Some module designs encourage this sort of interconnectivity by offering signal outputs beyond what is typically expected in a component of that type. For example, some envelope generator designs such as the Malekko Richter Envelator (Richter Envelator, 2013) will produce a gate signal upon reaching the end of particular stages of the envelope, or a delay module such as the Make Noise Echophon (Make Noise Co. | Echophon, n.d.) that offers a clock output based upon the speed of the delay. The connection possibilities encourage the formation of cascading relationships within the system, further adding to the complex interconnection of modules within the system.

Flexibility of Function across Broad Timescales

In the context of working with the Eurorack format, and in particular, modules based upon analog circuits, I found that I began to understand the functionality of a module in a more abstract way due to the lack of a conceptual and functional separation of faster audio rate signals, slower control signals, and binary state trigger and gate signals. If a low pass filter is designed to stop higher frequency signals from passing, then this might be applied to slew a control signal or produce an effect upon an audible waveform. I have found that this understanding of a module's function in the dual contexts of audio frequency sound generation and slower control signals encourages me to think laterally as I develop systems with the instrument. An example of an outcome derived from this type of thinking is the use of an oscillator running at a slow LFO rate, and using a variable pulse width output to sequence variations in the length of the gate signals produced by the oscillator. As the gate signal is combined with other gate and trigger signals through a logic circuit, the variance in the gate length can result in complex rhythmic combinations from the logic circuits AND or exclusive OR outputs.

Overlapping Design Influences

In the context of building my own instruments in a software environment I would usually start from scratch, building functional components from low-level elements. While the approaches I took were necessarily aligned to the paradigm of the software I used, I could usually build something in a way that reflected my own idiosyncratic schema, allowing possibilities that I had envisaged and designed. In the shift to a hardware modular instrument, and the process

of selecting individual modules for the instrument, I found that a module usually consists of a functional block of elements that in the context of Reaktor (Komplete, n.d.) or Max (Cycling ’74, n.d.) would itself be configured from lower-level elements. Most modules seem closer to the concept of an instrument than a neutral building block, each carrying its own design intentions, aesthetics, preferences, and idiosyncratic functions. Through the process of selecting modules for my instrument I found that I was in fact selecting and combining different design intentions, and the processes and ideas emphasised and supported by these components became a central concern of the selection process.

This aspect of my experience with modular synthesisers has stood out as being particularly unique to these instruments. If I were to research and buy a self-contained synthesiser, sequencer, or software plugin instrument, then I would also be engaging with the instrument’s idiosyncratic design intentions. However, in the context of a modular synthesiser these component designs are enmeshed together, interacting and impacting upon each other in a semi-integrated fashion. I have found that the process of selecting modules for my instrument is as concerned with choosing sources of inspiration, suggestion, and influence as it is about enabling particular functionalities within the instrument.

Continuous Signal

In sharp contrast to my experiences of working with software-based or MIDI-controlled instruments, many signals within a modular synthesiser patch flow continuously and are not dependent upon the initiation of discrete musical events. A range of components typically used in a modular synthesiser are concerned with interrupting this state of continuous flow, such as voltage-controlled amplifiers (VCA) that are used to attenuate signals until other processes invoke the amplification of the signal, or sample and hold circuits that arrest a signal to prevent further change until desired. These interruptions to the flow of signals are typically invoked to enable more deliberate, compositional operations. This aspect of working with a modular synthesiser stood out to me in comparison to my previous experiences of electronic instruments, where musical events and changes are by default deliberate, delineated, segmented, and controlled. This aspect of my experience of working with a modular synthesiser emphasised the instrument as seeming to have a level of agency and vitality that I needed to respond to, curtail or sometimes encourage.

Complexity, Systems and the Modular Synthesiser

Concepts relating to complexity and complex systems have been foregrounded through my experiences with the modular synthesiser. My experiences of relatively simple and linear

components in a modular synthesiser interacting to produce unpredictable and dynamic behaviours through interconnection, feedback, and recurrence, aligns well with the concept of complex systems (Rickles et al., 2007, p. 933). In the process of building a new patch, the system becomes more complex as more connections are made. Once a patch is built it is often so complicated that I would need to retrace the connections back through various components to understand a particular aspect of its function.

Complex systems are also described as producing *emergent properties*, essentially outcomes that cannot be easily deduced or predetermined from the knowledge of a system's components and its interconnection (Rickles et al., 2007). A key component of my experience of working with modular synthesisers has been the encounter of unexpected and surprising outcomes from systems that I have devised. Joel Chadabe also described his experiences of complex compositional systems he had devised as resulting in "whimsical, unpredictable elements" (Chadabe, 1984). It may be that this is simply a reflection of the underlying intention of designing and using compositional systems; that its results will surprise the composer. The process of designing and adjusting such systems is a process of corralling the surprising results closer to territories we find pleasing or interesting, rather than only surprising.

Another characteristic of complex systems is described as s*ensitivity to initial conditions* (Rickles et al., 2007, p. 934), which refers to the influence of slight differences in a system's state leading to dramatic differences in its output. In my experience of working with the modular synthesiser to create complex systems I have found that very slight changes in only one or two parameters will result in large-scale changes in the system's output, or produce substantial shifts over a period of time. This in turn has impacted upon how I approach interventions in the system, often 'performing' the instrument system through very slight adjustments to key parameters that result in radical shifts in its output.

Complex systems can be described as being *deterministic*, meaning that the function of the system's individual components can be understood, and even modelled, and the unpredictable nature of its output can be seen as a result of the interconnection within the system (Bertuglia & Vaio, 2005). Despite this unpredictability, this behaviour is not random; it is determined by the system and its initial conditions. Over the time I have worked with a modular synthesiser I have periodically tried introducing modules designed to explicitly introduce varying levels of indeterminacy to the instrument system. However, each time I have found the use of these types of modules to be deeply unsatisfying. The inclusion of indeterministic elements in an already complex system makes it very difficult to understand the behaviour of the system, or the influence of particular parameters upon the behaviour of

the system. While I am drawn to the unpredictability of complex systems, it is still my intention to practise with and learn the system so that I can perform meaningfully with it. When indeterministic elements are involved, I am left wondering if a change occurred due to an intervention I have made, or because of a randomised element within the system. When I am working with a complex system that is purely deterministic, I can alter parameters so that the system returns to a state that I have previously encountered, or gradually destabilise the system's state to progressively shift into unknown or chaotic territory as an intentional strategy.

Improvising Provides Protection from Entropy

Initially introduced in the field of thermodynamics, the concept of *entropy* is now used in a range of contexts to describe the propensity of a system to move towards an increasingly disordered state (Morin & Montuori, 2008). I found this to also be true in the context of a complex system patched within a modular synthesiser. My experience of improvising with the instrument is often a process of subtly managing and shepherding the system to prevent it from falling into a chaotic disorder outside of my own compositional intentions, aesthetic preferences or comprehension.

No Recall of Saved State

Another aspect of the experience of using a modular synthesiser that comes to the forefront in contrast to using software, or even most other hardware-based electronic instruments, is the inability of a modular synthesiser to save and recall its state due to the use of physical patch connections to define the instrument's configuration. While this limitation is certainly inconvenient, it is an aspect that I have found to bring pressure and direction to my creative process. The inability to save and recall a particular state means that the current configuration of the instrument must be recorded, performed or discarded before the instrument can be reconfigured for another purpose. In my experience of using software-based instruments and processes, I would find myself saving everything I did in the hope it might be useful later, or that I might return to develop that approach further. Much of the time this led to catalogues of old projects that I never returned to, but I always felt somewhat deficient for having abandoned them. I have found this limitation encourages me to develop a disciplined approach to assessing and abandoning specific configurations of the instrument, trusting in my ability to build a new and improved patch in the future rather than collating every possibility encountered along the way. As a result, I found myself enacting the process of constructing a patch much more often than I had with software-based

patching instruments such as Reaktor or Max, where I would more likely recall, refine or modify an existing patch.

I found the intensely iterative process of creating and dismantling a patch led to a proficiency and in-depth understanding of the instrument, making the process of patching quicker and more assured in the types of outcomes that would occur. This process of repetition also allowed me to gradually refine particular components of a patch, reusing and adapting them to other purposes in new patches.

Live Electronic Music: Practice is Performance

The inability to save and recall states presents a serious challenge when approaching live performance. Most digital electronic music equipment orientated towards live performance emphasises the ability to recall and switch between particular sounds or sequences on the fly. The process of electronic music performance seems to often be reduced to the sequential recall of patterns, loops, and predetermined synthesised voices, combined with mixing of sources, application of effects, and the adjustment of a few parameters. The act of electronic music performance in this case is assumed to be a real-time arrangement of elements, most of which are prepared in advance of the performance.

The paradigm I have described of electronic music performance separates the processes of composing and creating music from performance of the music. In my experience as an artist and audience, the act of performing electronic music often seemed to be a fabricated and abstracted representation of components of the compositional and production processes. As an artist I would select discrete elements of the music I was recording and arranging that I thought could be managed in a live context, the risk of failure and possibility of new permutations being key indicators of the liveness that these elements offered to the performed version. Other elements would be automated or semi-automated, such as prerecorded audio and MIDI files, pre-devised parameter changes, or predetermined arrangement sections. Similarly, as an audience member, I could usually determine to some degree how a performer has chosen to approach their live performance based upon their interaction with their equipment and how exact a replica of their recorded work the performance seemed.

In my experience, the inability to save set-ups in the modular synthesiser shifts the act of performing much closer to the act of composing, in some cases rendering the two processes identical. In a studio context I would improvise with a pre-constructed patch and make recordings, and in a live performance I would also improvise with a pre-constructed patch.

This closer alignment of studio practice and performance practice has become a key motivation for my use of modular synthesisers, allowing the skills and processes I develop to be used across both contexts.

Processes and Possibilities Intrinsic to Modular

My initial interest in using a modular synthesiser was focussed upon affordable and flexible analogue sound, and in particular the possibilities for analogue audio feedback, which I had found to be problematic in a software-based environment. My interest quickly shifted to processes and devices that form musical structures as real-time operations. For example, the use of clock dividers and logic gates to form rhythmic patterns was a process that I had not encountered with either hardware- or software-based sequencing instruments. As this approach forms patterns in real time rather than being encoded in advance, there is no timeline with periodic events predefined; instead, the process can be continuously intervened into and complexified through other real-time periodic or aperiodic systems.

While all of the possibilities for generating musical structure in real time with a modular synthesiser are possible using a software-based approach, particularly in visual programming languages such as Max and Reaktor, the possibilities I found myself exploring with a modular synthesiser were distinct from my experiences with software-based approaches. In some cases, I became aware of approaches through the various modular synthesiser user communities with which I engaged, but I also found that the modular synthesiser paradigm emphasised particular approaches that I had not encountered in a software environment. The compositional ideas that I generated and pursued through use of the modular synthesiser were new and unique in comparison to those I had pursued previously using software.

It would be impossible to make a blanket statement that defines the compositional approaches I discovered through my use of a modular synthesiser that I felt to be distinct from those I previously encountered in a software environment. However, below are some qualities and attributes that these approaches exhibit that provide a level of description.

Simultaneity

Due to the analogue nature of most modules and the analogue history of modular synthesisers, the processes enacted with the modular synthesiser are simultaneous and situated in the moment. There are no limitless data sets that can be indexed, written to, and read from to manipulate parameters. Instead, the complex interactions flow from one

moment to the next, relying upon distinct components such as sequencers, sample and hold circuits, and switches to retain and reuse magnitudes of voltage. These components by their nature are limited in the quantity of values they can retain, and often reliant upon linear recollection of these values.

Single Bit Operations

Due to the prevalent use of gates and triggers in the modular synthesiser paradigm I have found myself working more with complex interactions between these one-bit values, such as Boolean logic gates, cascading gates, clock dividers, redirection of triggers or gates via switches, and combining and mixing of gates signals to form more complex values.

Intensive Component Interaction

As previously described, the limited number of modules available in a given modular synthesiser seems to result in a more intensive interconnection between components. Whereas in a software environment I might instigate multiple components such as LFOs to achieve an idea, using a modular synthesiser this may not be possible. This situation seems to be reflected in the design of many modules, where various control voltage, gate, and trigger sources are available simultaneously to allow a component to undertake multiple roles at once.

A Physical Instrument

The physicality of the modular synthesiser in comparison to a more computer-centred approach is likely the most immediately apparent contrast. This aspect of the instrument has appealed to me in a range of ways.

Audience Engagement

After many years of performing with a laptop and little else, I have found audiences seem more receptive to watching a modular synthesiser performance, often coming to chat afterwards and expressing interest in the instrument. In comparison to the laptop, I assume that the unique form of the instrument, the visual complexity of a patch, and more discernible interaction all play a role in this engagement.

Permanence and Presence

I have found the dedicated nature of a modular synthesiser, as opposed to a laptop that performs a range of functions, to assist me in building discipline to work with the instrument.

Just the presence of the instrument in a room is noticeable and a constant reminder to engage with it, whereas a laptop represents many activities.

Interface Embedded

An aspect of performing with a laptop that I often struggled with is the question of interfacing in order to improvise and perform. I tried a range of peripheral controllers in conjunction with a laptop, and my use of them was usually predicated upon the particular patch or instrument I had built. When the patch I was using changed, the interface would sometimes make less sense and seem less connected to what I was attempting. I also found that the controller I was using would influence the approach I took in the software patch, matching functions and parameters to the controls available on the interface. This sometimes sat uncomfortably with me, as the controller is usually a fairly generic collection of knobs and sliders, often designed with more typically DJ or dance music-oriented approaches to music making in mind. In the case of the modular synthesiser, there is no need for a performance interface as the instrument already has a defined interface. I found this aspect of the instrument made my use of it both clearer and more defined, and removed the need to separately consider the instrument and its interface.

Concluding Creative Practice

The detailed explanation of my experience of working with a modular synthesiser presented in this chapter provides some insight into how I use of the modular synthesiser and the ways in which that has evolved, demonstrating something of how my experiences have impacted upon my processes of music making, and why I value this experience.

The key themes that emerge from this reflection include:

- Reuse and exploration of sub-patches or system components, where practitioners build a mental library of approaches that can be appropriated and developed as they construct new patches.
- Creative constraints and integration of diverse design intentions enforced by the modular due to its hardware-based format and the philosophies embedded in each module design.
- Experiences of complexity where instrument systems become too complex to understand and predict.

- Nature of analog signals and their operation across broad timescales from structural components to discrete music events to formation of audible frequencies.
- The impact of the modular as a physical instrument on performance and improvisation practice, enabling highly specialised instruments to be formed that draw upon and embed a broad variety of techniques and processes associated with electronic music.

The incorporation of discussion of my creative practice as a formal component of this research conforms with the phenomenological process of Epoché. Engaging in this process has enabled me to include and make explicit my own experiences and interpretations of using a modular synthesiser. These insights have assisted my efforts to analyse the data collected from other participants and understand their experiences at a deeper level than if I were uninvolved in the activity being examined. In many cases my own interpretations were not in alignment to those expressed by the research participants, and this provides reassurance that my analysis is not entirely bound by my own experiences.

The insights uncovered through my reflective practice are incorporated into the thematic analysis provided in Chapter 6, alongside the experiences of the research participants (see Chapter 5) and the historical context provided in Chapter 1.

Chapter 5. Practitioner Interview Data Analysis

A series of twenty-one interviews were conducted with musicians with the goal of understanding how modular synthesisers are used, how the experience impacts upon the process of music making, and why the experience is valued by musicians. As detailed in Chapters 2 and 3, my analysis of the practitioner interviews and my subsequent identification of thematic descriptions evolved through my engagement with the phenomenological research processes of Epoché Phenomenological Reduction and Imaginative Variations. This chapter details the thematic descriptions identified through analysis of the participants' interviews. Direct quotes are provided amongst the themes to support and illustrate the basis for the themes' identification. The chapter starts by describing the sample group of participants and the process of recruitment. A complete account of the research design is given in Chapter 3.

The themes that emerged from the interviews identify the role of the modular synthesiser in practice; how the participants came to using the modular synthesiser in their practice; descriptions of the processes and experiences of creating music with a modular synthesiser; participants' experiences of choosing modules, curating, configuring and developing their instruments; participants' experiences with communities that are connected to modular synthesisers, and finally, comparisons to the participants' experiences with other instruments or music making processes.

Research Participants

Research participants were initially approached via networks and contacts I could already access. I prioritised the representation of a variety of approaches considering music genre, and live or improvised practice. I employed a process of snowball sampling (Given, 2008) seeking recommendations from each participant, asking if they knew of someone whom they thought would be interested in being involved in the research, or who might have an interesting practice worth investigating. I also approached Melbourne Electronic Sound Studio (MESS Ltd, n.d.) for recommendations of potential interviewees whose practice would be of interest.

An even representation of gender was prioritised in the process of identifying research participants and this resulted in ten of the 21 participants identifying as female or non-binary.

Geographically, some participants were based in the United States or the UK, but the majority were based in Australia. Although information on the financial circumstances of participants was not gathered, it can be assumed they were from a fairly broad range of financial circumstances. Many were practising artists who work in other occupations to make ends meet, while some were professionals presumably with greater access to financial resources. Ages ranged from 21 to 87 years old, with most participants being between 25 and 50 years of age. For an overview of the participants see Sampling and Recruitment in Chapter 3.

Role of Modular Synthesiser in Practice

Interviews with participants revealed a range of approaches and attitudes regarding the function of the modular synthesiser in their practice. The following descriptions are not intended to represent attractors for, or the intentions of participants, but instead broadly describe how the modular synthesiser is situated in the participants' workflows. Some participants use their instrument in multiple, but distinct modes depending upon the project or task they are attending to. Despite this diversity, three principal roles or functions can be identified: the modular as a stand-alone instrument, as a synthesiser voice, and as a sound design tool.

Stand-Alone Instrument

The most commonly encountered approach situates the modular synthesiser as a stand-alone instrument that produces audio, and is also responsible for producing control signals and musical events for itself through a variety of approaches. The instrument may still receive some control signals from other components of their set up, such as a MIDI clock to drive tempo-related components, or the modular instrument may at times control external equipment in addition to its own parameters. The concept of the *instrument* and *instrumentalisation* is a significant feature of these accounts, and blurs the distinction between a traditional performance instrument and a compositional tool. These ideas are taken up in more detail in the discussion in Chapter 6.

Synthesiser Voice

In this mode of use the modular instrument is controlled by an external device, such as a DAW or a hardware-based sequencer. This is achieved using MIDI signals via a MIDI to CV converter, with CV directly via a DC-coupled audio interface, or using dedicated CV outputs

on the sequencing hardware. Participants using their instrument in this way may not exclusively generate musical events externally. Complex interactions within the modular synthesiser may still be devised that generate or modify the timing, pitch or other attributes of the instrument's audio output. However, cases contributing to this theme significantly favour external sequencing as the primary mode of musical event generation for the modular instrument.

Sound Design Tool

The third of these categories refers to use of the instrument as a source of sound generation that is then recorded and reused, either in a DAW or other instrument, or via a sample playback module in the modular synthesiser itself. Internal or external control signals may or may not be utilised. The intention is not to compose something as a finished recording or performance but instead to create elements of sound that may be used or manipulated further in subsequent compositional processes.

Coming to Modular

A section of the interviews asked the participants to describe how they came to use a modular synthesiser. In some cases this elicited a long narrative, describing key experiences the participant identified as contributing to their interest. The following themes group together common experiences or describe unique cases. In some instances participants are represented in more than one theme. By examining these musical trajectories we can start to understand how the modular impacts upon the process of music making, and why the experience is valued by musicians.

Synthesiser and Music Technology Enthusiasts

Some participants describe a long-term interest and involvement in electronic music and synthesisers, sometimes over several decades. The shift to modular synthesisers for these participants occurred in the last five to ten years as the resurgence in modular synthesis grew and interest rose, particularly in the Eurorack format.

One participant’s initial foray into modular synthesis was encouraged by their experiences of vintage analog synthesisers breaking down and needing expensive repairs. They became aware of various copies or clones of elements and components from vintage synthesiser

designs and decided to instead invest in the Eurorack format as a newer, more sustainable and flexible option (Participant 1).

> *I think it came initially because I was very into vintage synthesisers, Moogs and Rolands and, kind of, was getting them and frequently finding them more and more difficult to repair.* Participant 1 interview 2020.

Coming initially from a broader interest in music production and rock music, another participant found the possibility for a modular synthesiser to be a flexible studio tool compelling. As they gained more experience with their modular instrument, they developed a strong interest in electronic music (Participant 17).

> *Then I started thinking about… how to make interesting music and then listening to production from people who really took the kind of paradigm that the Beatles really worked with…with the studio as the instrument. I really took that on and saw that as the kind of the modern way, make music interesting music…. and so, for me, modular is a perfect exemplar of this is, it's the way to actually create something that is so embedded in, in everything that you do, I can feed external things into it.* Participant 17 interview 2020.

Other participants simply found themselves drawn to modular synthesis following on from long-held interests in fixed architecture synthesisers. They became aware of new module designs available in the Eurorack format that enabled possibilities previously unavailable in physical hardware-based instruments or noticed other performers working with modular synthesisers. They engaged in various online communities dedicated to modular synthesisers before beginning to develop their own instrument (Participants 5, 19, 20).

> *I had a laptop, and I had a virus snow synthesiser and that was my… first real… access to sort of non in the box production... I then bought a, uh, Moog Little Phatty… and then have just slowly become more and more addicted to synths and buying synths over the years. And Eurorack was something which I had heard about like even from the early days, [I was] always very much into audio technology. So, and the, the entire Eurorack format was something that I'd kind of heard a lot about and was really curious about but didn't really know if I wanted to make the financial commitment to get involved in it. Then one day I just decided to take the plunge.* Participant 19 interview 2020.

Community

A number of participants described formative interactions with groups or individuals who already worked with modular synthesisers. In some cases, this was a one-on-one interaction or series of interactions with someone who gave them the opportunity to try out a modular instrument and encouraged their initial efforts (Participants 4, 10, 18, 21). The concept of community as central to the contemporary modular experience is developed in the discussion in Chapter 6.

> *I worked with a friend and other friends a couple of times… who did kind of sound design for theatre shows that I had worked on. He was using a small modular rack, Eurorack. I just became pretty fascinated in what he was doing with that synth and just kind of interested… in the sounds that I could make, which were quite different to what I was doing with the JP08. It kind of gave me this sense that there was another world of synthesis to explore beyond the traditional kind of analog subtractive synth techniques that I had been used to.* Participant 18 interview 2020.

Melbourne Electronic Sound Studio Foundation

Two participants had experiences at the Melbourne Electronic Sound Studio Foundation (MESS Ltd, n.d.) where they were able to try out a range of instruments and were supported by MESS staff (Participants 4, 18).

> *I moved to Melbourne… and when I moved here, I had heard about it [Melbourne Electronic Sound Studio] and I was like, I would love to play around with these synthesisers that I don't know that much about. And then I came here and did a session on the Buchla, not knowing what I was doing at all. I was feeling a little bit nervous about the whole thing, cos they're quite confronting as machines I would say. But there was something about [it], I couldn't even explain what the attraction to this one was. I feel like maybe it's the weird kind of '80s sci-fi, '70s–'80s sci-fi vibe or something, like there's something endearing about it. Robin Fox [was] minding the studio and he kind of offered for me to play through speakers cos there was no one else around and that made me really anxious. Cos I was like, I don't know what I'm doing, I don't want anyone to hear this, but I went ahead and did it anyway. And by the end of the session, he was just really excited by whatever I was doing. And honestly, I was just plugging things in, I didn't know what was going on. It was just a little trial and error journey, which to be honest, it's probably still the way I work, but just with more knowledge behind it now through experimentation. By the end of it, he offered me a*

> *residency here. Um, so then I got to spend quite a significant amount of time here and I focused it all on this Buchla synth. And then that was kind of the entry point. And now... I just explore through any, any access I can get.* Participant 4 interview 2020.

Nonlinearcircuits / Artifactory

One participant initially encountered a community through a series of experimental music gigs and then became involved in a series of DIY module building workshops run by Andrew Fitch of the modular synthesiser company Nonlinearcircuits (Nonlinearcircuits, n.d.). Over the course of several years, they built their own modular instrument using predominantly DIY Nonlinearcircuits designs and began performing at gigs themselves (Participant 9).

> *I… came across the community through this place in Perth called the Artifactory and its sort of a hackerspace… They have a regular gig there, an experimental music gig, and I started going there regularly and then meeting a crew who build their own synths. I'm not sure if you're familiar with Andrew Fitch, he designs modules… then I started going along to sessions and building stuff. So, it's been, I don't know how long, maybe three or four years. And I'm sort of building and collecting and then started performing with them maybe two years ago.* Participant 9 interview 2020.

Semi-Modular

Some participants' initial experiences of working with control voltage was through semi-modular instruments that have a fixed architecture that can be modified, circumvented or interrupted through various control voltage inputs and outputs (Participants 11, 13, 14). Instruments cited include a Korg MS-20 Mini (Korg MS-20 | Vintage Synth Explorer, n.d.), a Moog Mother-32 (Mother-32 | Moog, n.d.) and a KOMA Field Kit Electro Acoustic Workstation (KOMA Elektronik, n.d.). Two participants sought to augment these semi-modular instruments with a small collection of Eurorack modules (Participants 11, 14).

> *I started out using just like a little Moog Mother and I was thinking that I would pilot that from the computer, integrate Max with hardware, and then working with hardware was just too fun. So I bought a [Eurorack] skiff, and then… went up to the 12u [Eurorack].* Participant 11 interview 2020.

Pedals

One participant who was initially a guitarist began working with a Moog Moogerfooger Ring Modulator pedal. They realised the potential for sound design and generative music, quickly selling most of their guitar pedals to buy a modular synthesiser (Participant 2).

> *My primary instrument was guitar at that time… At one point I bought a ring modulator, like the Moogerfooger ring modulator [pedal] to use with my guitar set up. And then like within… a few months was selling my [guitar pedals], [I] really like quickly saw the… sound design and… generative composition possibilities within a modular setup was something that was going to be really interesting to me.* Participant 2 interview 2020.

Patching in Software First

One participant initially worked with Cycling ’74’s Max software (Cycling ’74, n.d.) but upon encountering modular synthesisers through a music industry exhibit realised that they would prefer to patch using a physical interface (Participant 3).

> *I was interested in it [Max/MSP] ... then I saw the modular synthesiser… at the NAMM convention. That's when I really knew that it made more sense to patch with your hands instead of with the mouse for me.* Participant 3 interview 2020.

University

Some participants initially encountered modular synthesiser instruments through their studies at university. These experiences included accessing studio spaces with one or more instruments, participating in classes where these instruments were introduced, and rescuing vintage instruments from the institution's dumpster (Participants 6, 8, 15, 16).

> *So [I] basically went to school to study music, but mostly to study computer music. But of course, when I got to Berkeley, they had all this great infrastructure. One or two, one of the main engineers at ARP was working there at the time. So there was a lot of ARP equipment at the school. And you know, all of the computer music workstations with like a couple of rackmount bits of gear, like an Oberheim Expander and a Roland JP 8000 and a couple of other things. They had some rudimentary modular stuff. I think they had one EML in one of the studios and they had ARP 2600s, semi modular… instruments. And I really got interested in this stuff because everything in the box was so rigid and kind of…. very routine.* Participant 6 interview 2020.

Deviations from Initial Intentions

In some cases, participants had a clear intention for their use of a modular synthesiser when they initially began to use one, but through their experiences shifted their intentions and workflows.

Flexible Fixed Architecture

A participant initially began using a modular synthesiser with the intention of creating an instrument that combined various elements of ‘classic’ vintage synthesisers such as a Roland 303 (Roland TB-303 | Vintage Synth Explorer, n.d.) with components based upon other synthesiser designs. Their intention was to emulate a typical fixed architecture synthesiser design but with the flexibility to customise the voice with combinations of components. They quickly encountered components with capabilities unique to modular synthesisers and as a result shifted their intentions to a much broader exploration of modular synthesis (Participant 1).

> *I just started to see, oh, if I had a modular, there's… a clone of that great filter. Oh, imagine if I combined that with the envelope, from that cool synth; you can do that now.* Participant 1 interview 2020.

Integration with Software

Another participant initially intended to closely integrate and control external modular and semi-modular instruments using DC offset voltage produced by software. As their experience of modular synthesisers progressed, they realised that they were more interested in the modular instrument being a stand-alone instrument controlled through performance or internally generated control voltage signals (Participant 11).

> *I started out using just… a little Moog Mother and I was thinking that I would pilot that from the computer, integrate Max with hardware. [But] then working with hardware was just too fun. So, I bought a [Eurorack] skiff, and then kind of went up to the 12u [Eurorack]. And, and now I kind of view it more like an instrument in and of itself… I don't often integrate it with the computer that much. I mainly just use the computer to record it, mix or whatever. There's been a few times that I've interfaced it… sending CV out, that kind of thing. So, I think it's probably been a good two, three years that it's been my main instrument. I perform with it; I compose with it. But mainly real-time stuff that then I edit later.* Participant 11 interview 2020.

Elements of my own trajectory are reflected in these accounts, however what is significant is the diversity of processes by which electronic musicians have found themselves attracted to the modular in terms of how modular synthesiser might be used, how the modular impacts upon the process of music making, and why the experience is valued by musicians.

Composing with the Modular Instrument

Themes organised under this section relate to the process of creating music, whether that be through live improvisation or a studio-based practice. A broad range of activities and interpretations are described, from the experiences of working with indeterministic processes and generative systems, to the experiences of connecting modules to form a patch, and the challenges presented in the experience of composing with a modular synthesiser. With the aim of capturing depth as well as breadth, this section includes four brief case studies of compositional approaches, focussing on controlled indeterminism, generative systems, and interfaces for improvisation.

Discovery and Exploration

A common theme described by participants was a desire to explore and discover musical forms through their use of their modular instrument, often situated in contrast to pre-planned modes of composition where musical ideas are conceptualised and then enacted with the assistance of the machine. This aspect of working with a modular synthesiser was described as an experience they felt was unique to these instruments.

> *The end goal for me is to have a space that I can explore and have fun in, you know, it's not to be able to know every nuance of what's going, going to, to happen.* Participant 1 interview 2020.

Some participants characterised this experience by allocating the modular synthesiser its own agency, describing processes where they situate themselves as collaborating or co-creating with the instrument

> *So yeah, it's very much about kind of finding the voice of the synthesiser, so to speak, and kind of following that and performing with the machine.* Participant 19 interview 2020.

> O*ne of the things that I really like about working with modular is that it surprises you and gets you to start looking at things that maybe you wouldn't have thought of. It's like this conversation with the machine.* Participant 4 interview 2020.

Other participants framed this process of discovery in music composition as the instrument being a form of material that suggests its own possibilities and outcomes.

> *Being in the studio is basically just making one decision after the next all day long, you know, and… if you have a practice that's experimental in any way whatsoever, you're receptive to the influence of the material changing your decision making.* Participant 2 interview 2020.

This process of being open to and working with possibilities suggested by the instrument was also described as a sort of journey that leads the composer into unexpected musical territory.

> *I always feel… subconsciously drawn to this way of making music that ...leads you down this garden path towards... psychedelic sonic spaces.* Participant 18 interview 2020.

Indeterminism

Some participants reported use of specific modules and processes that embed a level of indeterminism into their compositions through the patching of the modular synthesiser instrument.

> *I really liked these source of uncertainty modules because, um, I think something that I like about modular, talking about them being surprising and stuff like that, is that element of potential randomness and things like that and kind of letting it have a random voice in how you're building things.* Participant 4 interview 2020.

This embedding of indeterminacy in the instrument itself was identified as a unique aspect of modular synthesisers, and some participants attributed indeterminacy to a *west coast* style of synthesis. West coast, in the context of modular synthesisers refers to the Buchla, and Serge instruments each being developed in California on the west coast of the USA, in contrast to the Moog instruments being developed in New York state on the east coast of the USA. The term is often used as shorthand to refer various preferences attributed to each designer, for example, Moog's eventual preference for a keyboard in contrast to the Buchla and Serge instruments' avoidance of a keyboard as a default interface.

> *But I really like the random nature of the system that I've put together. There's a lot of modules which I bought, which... gravitate to sort of west coast kind of focus... synthesis, which was an entirely new thing for me before getting into modular synthesis… getting into a system where the uncertainty was a big part of the instrument... was kind of really inspiring.* Participant 19 interview 2020.

The role of indeterminacy in the practice and workflows of the participants varied broadly from slight variations of timbre through to entirely randomised sequencing of pitch and gates. A common theme, however, was the desire to impose a level of control over the indeterminacy through attenuation and offset of voltage.

> *I found using an offset I can set the pitch range or the speed range, or like get it in the range I want and then use this gesture to, to really zero down on texture, um, without losing the pitch, or you know, things like that.* Participant 1 interview 2020.

Some participants also used modules designed to capture randomly generated CV or gate signals so that these could repeat or be otherwise utilised without further variance unless specified by them (Participants 8, 19).

> *What I love about the Turing Machine most in terms of this kind of quasi-randomness that it puts out is just being able to lock it off.* Participant 8 interview 2020.

Vignette: Controlled Indeterminism (Participant 19)

The participant used a Sapèl Tamed Random Source module by Frap Tools (Frap Tools, n.d.) to produce two channels of random gates and two channels of random CV that are then fed via a quantizer (Ornament & Crime, n.d.) into a Bishop's Miscellany module by Shakmat Modular (Shakmat Modular — Bishop's Miscellany, n.d.) that can record and playback up to two channels each of gates and CV from a maximum of 32 steps. The Sapèl is also used to provide a regular clock signal to the Bishop's Miscellany so that the two devices are tightly synced together. The Bishop's Miscellany is then able to play back these recordings of CV and gate signals through its own outputs, which has been patched to control the pitch of two oscillators and trigger envelopes that shape the amplitude of each oscillator. This system enables the participant to capture and loop the random material generated by Sapèl, and then shift the section and length of the playback, effectively scanning back and forth across the

recorded CV. New material can be added incrementally by enabling ‘Record’ again, in the same way that ‘punch-in recording’ can be used in a DAW or tape recorder.

In this patch the Bishop’s Miscellany module allows sequences of quantised CV and gate signals to be captured and replayed, thus allowing repetition of meso-scale musical structures.

In more complex patches the participant automates the selection of loop length, pattern start, and pattern reset of the Bishop’s Miscellany using clock dividers, Euclidian clocks and low frequency oscillators (LFO) to create complex patterns that only repeat over a longer period of time, or even morph slowly via automated control of the record function. This system enables the participant to quickly generate melodic and rhythmic structure that they can then manipulate, replace or mutate gradually.

The participant has little influence over the material generated by the Sapèl module but regains control as it is captured and played back by the Bishop’s Miscellany module. The repetition of the looping material enables more conventional conceptions of musical structure to be constructed in real time; they are able to improvise at this structural level, either through direct manipulation of the modules or through more complex systems of CV control.

Generative Systems

Participants described and demonstrated both simple and highly complex patches where the instrument controlled or ‘played’ itself to varying degrees. This section focuses on the use and experience of systems that generate music and the relationship of the participant to these systems. Randomised generation of control voltage signals may have been utilised within the systems described but not in all cases. Participants focussed on the system itself rather than discrete events, treating the system as the composition. Some conceived this as a form of abstract control, or that this abstraction resulted from a high level of complexity in the patch, and in some instances this resulted in a shift from composing to listening or, more interestingly, to the idea of listening *as* composing.

Focussing on the System

> *I want to be focused on, on the system, not the literal events that I'm creating.*
> Participant 17 interview 2020.

A desire was described by participants to shift their focus away from compositional decisions that situate defined musical events and expressions at particular moments in time, to instead develop systems in their instrument that could result in a range of permutations (Participants 17, 2, 6, 19). Their role as composer is to specify and modify the range of possibilities and internal logics in the system or patch so that it produces results of interest to them.

> *It's like I don't have that total control over the music it's making at an atomic level… I'm just sort of reigning in more than I'm actually composing or controlling or making… Delineating as much control as possible to the system, you know, and knowing comfortably within a certain set of parameters what it's going to do and how it's going to do it.* Participant 6 interview 2020.

Some participants designed their systems to create continual variations, never repeating the exact same pattern but remaining within a broad but somewhat recognisable motif (Participants 2, 6) while others worked with more repetition of phrases generated by their system, denoting when changes and permutations could occur (Participants 17, 19).

Participants emphasised the importance of their active involvement in the system to varying degrees, some declaring a desire to be very hands-on and active in the process (Participants 5, 13), while others saw their role as a form of oversight, intervening and modifying from time to time (Participants 2, 6).

Case Study: Simple but Complex (Participant 6)

Developed, refined and performed by Participant 6 over a number of years, this patch is centred upon the use of two LFOs (low frequency oscillators), one producing a slow sawtooth waveform and the other a square waveform forming a trigger signal source. The voltage from the sawtooth LFO was fed into the input of a four-stage shift register via a pitch quantiser, with the other LFO’s square wave feeding the shift register’s trigger input.

A shift register is effectively a cascading series of sample and hold circuits. As a trigger is received, the voltage level of the first output is updated to match the voltage of the input. The second output then takes on the voltage of the first, and the third output updates to the voltage of the second and so on, so that the voltage level is passed along the line of outputs.

Each of the four outputs of the shift register is routed to the pitch control input of an oscillator. The four oscillators each have their volume controlled by dedicated envelopes that are triggered by the same LFO as the shift register.

Participant 6 performs the patch by adjusting the speed of each LFO, often adjusting them to run slightly out of phase. The patch results in a cascading non-linear series of notes that vary depending upon the relative speed and phasing of the two oscillators.

Participant 6 commented upon the complex variations possible just by varying the speed of the two oscillators:

> *I got really into the kind of spaces within the relationships with those two timing engines that were just slightly out of phase, which create all these really beautiful alinearities and of course you're, you're working in analog, so the timing is never going to stay completely crystal in time with each other. You know, it's always going to drift somewhat… It's a really, it's a simple patch computationally. There's not too much going on with it, but it's one of those things that it's, you know, the devil's in the details and it kind of yielded a lot of really interesting material, like musically interesting material, not just computationally interesting.* Participant 6 interview 2020.

This case study illustrates how elements within a relatively small system can work together to produce complex material. Participant 6 in performing the patch was focussed on adjusting the parameters of the system rather than making decisions about discrete musical events.

System as Composition

Some participants identified the patch or system as being the composition itself, performances and recordings being a form of documentation of particular instances of the composition (Participants 2, 6). Other participants viewed the system only as a means to create compositions either in a live setting or recordings that could be edited and combined as a separate process.

Abstraction

Participants described a desire to shift their role away from making decisions about specific notes or other parameters in sequence and instead be focused upon the development of systems with their modular instruments that can be interacted with to produce new or

iterative variations of musical structures (Participants 17, 4, 11, 1, 6, 8). The experience of interacting with these systems was described by some participants as a form of abstraction; their decisions were not guided by a clearly defined mapping between their potential actions and the resulting outcomes, so their choices do not result in a predictable outcome (Participants 17, 1, 6).

> *The main thing I want to pursue with a modular is thinking about abstract control, and thinking about how to create a system of events which are or can be related to each other.* Participant 17 interview 2020.

This abstraction supports the participants to experience a sense of discovery or exploration as they interact with their instruments, encouraging them to take experimental actions without a preconception of the exact outcome. However, the operations they undertake are not random or without any insight to the processes they invoke; patterns, relational connections, and repeatable cause and effect all enable the musician to perform deliberately, plan and improvise.

Case Study: Theremin into JAG

Participant 1 demonstrated a technique with their Eurorack modular synthesiser that they often use to perform sweeping changes across multiple parameters of a patch. Using a Doepfer A-178 Theremin module (A-178, n.d.), they connect both its CV output and an inverted version of its output into a Malekko Wiard JAG (Joystick Axis Generator) (Wiard JAG, 2011). The Malekko Wiard JAG generates nine separate CV sources based upon the relative levels received at the module's two CV inputs, in this case the signals received from the theremin module.

The participant connects the nine CV outputs of the Malekko Wiard JAG to various CV parameter control inputs of the patch, often splitting the CV signals to allow each to control multiple parameters. By gesturing their hand near the Theremin these CV signals would all shift in different degrees, both increasing and decreasing, to effect dynamic changes to the patch:

> *For me it changed modular significantly because suddenly instead of, I mean, obviously you're patching, but just to have that moment where you're navigating the sound. And as you know, with modular, you change one bit of CV, you can set that to cascade and change 12 other things. So, when you've got that happening 10 times, suddenly you have this universe of different sounds and textures and timbres*

> *and rhythms that you're not, you're not trying to patch or do anything, you're just there and moving around.* Participant 1 Interview 2020.

Expanding upon this technique, they described the experience of modulating the playback point of a digital sample using an ER-301 module (Orthogonal Devices, n.d.) as a granular sample player:

> *[I]t's digital and you can see the waveform. So I can be flicking the waveform with my hand, but then I want to hold it still so that I can go and just hit it at the right time. But, of course, there's minute movement in my hand, so that's just wobbling a bit. And that, that wobble sends little granular textures out, and I have very little control over that, but that becomes part of the aesthetic, this kind of negotiation between the, the intention and what's given.* Participant 1 Interview 2020.

The participant also described the use of offsets and attenuation to the CV signals to limit and prescribe the range they want to work within from the JAG-generated signals.

> *I found using an offset I can set the pitch range or the speed range, or like get it in the range I want and then use this gesture to, to really zero down on texture.* Participant 1 Interview 2020.

This case study is an example of a participant deliberately relinquishing their ability to have exact control over their patch in favour of large-scale sweeping changes. The technique precludes particular combinations of parameters, effectively narrowing the possibilities available to them. This is traded for the experience of shifting many parameters through physical gesture to discover the results of these complex combinations.

Complexity

Participants reported experiencing various levels of complexity in their patches resulting from cascading chains of cause-and-effect relationships or co-dependencies between modules (Participants 1, 2, 18). This complexity was reported as a desired quality of the experience of using their instruments, contributing to the abstraction of their actions and situating their interaction with the system as a process of discovery.

> *If I can make it more complex than I can hold in my head I'm so much happier, because then it's that relationship with the machine that I'm exploring, not me pouring something out of myself, um, using a tool.* Participant 1 interview 2020.

These relationships may not be complex if considered in isolation, but when combined together or situated in recursive systems they can quickly become more complex than the participant is able to effectively hold in a cognitive map (Participants 1, 2, 18).

> *[T]hese relationships aren't complex in themselves, it's just like 'this sends a ramp here, this sends a beat when this happens'. And, but once those all accumulate, there's no way that you can kind of follow what's, what's going to happen. And it's like, you know, you set up all these kinds of chains of events.* Participant 6 interview 2020.

Instability and Small Changes

Participants related experiences where they would make very small adjustments to a patch that would result in significant changes to its output (Participants 1, 6, 11, 21).

> *It really made me focus on the small changes, you know, just like the small formal changes instead of worrying about all those things to worry about when you play live. It became more about just eking as much complexity out of that system as possible… the idea of what, what to change as I'm playing becomes just as simple as possible. Just one element at the time. Kind of highlight the changes instead of like having them all happen at once, and just kind of getting as much maximum drama out of the patch as possible.* Participant 6 interview 2020.

Listening to the System

Some participants noted a key aspect of their experience of composing with modular synthesiser based generative systems is an experience of listening to the instrument (Participants 2, 6). Differentiating from their experiences as instrumentalists, where the sound stops at the moment they cease playing the instrument, using a generative system they are able to step back and focus upon listening before choosing to intervene.

> *It's almost like you're making music by listening to music. And that was another aspect that I thought was really interesting... you relinquish control to the machine to make this thing for you and then entertain you and you love it.* Participant 6 interview 2020.

Patching the Instrument

The experience of patching is central to composing with the modular. This section focuses upon participants' reflections relating to their experiences of patching their modular instrument and working with voltage signals to establish relationships between modules.

Patching is characterised by transparency, difficulty and limitations, problem solving, immediacy, habit formation and discovery.

Patching Paradigm

A participant described the connections created using patch leads as being discrete, with direct correlations and a 1:1 relationship, reporting that this aspect made it easy to ascertain relationships between components even in very complex patches (Participant 6).

> *You don't have to use mental tricks to kind of remember what you've done. You can just look at it.* Participant 6 interview 2020.

This relative simplicity (often described in contrast to experiences of software) enables participants to intuitively create connections one step at a time, hearing any changes as they make each connection rather than needing to think several steps in advance (Participants 6, 8, 18). This caused complex systems to emerge gradually from discrete decisions and relatively simple connections (Participant 18).

Voltage Control

Participants noted the flexible nature of voltage control, in particular the interchangeability of audio and control signals (Participants 6, 8, 19).

> *Anything can control anything else. Audio can control audio… you don't really have to be too computational. You can be very intuitive and in the moment when you're playing it*. Participant 19 interview 2020.

Some participants used terminology usually reserved for the manipulation of tangible, solid materials, such as “carving waveforms” or “sculpting with voltage” (Participants 4, 8, 12).

> *It’s like sculpting with voltage. You have voltage running through the whole system and then you just decide to take some out of here and you put it in here… it feels kind of tangible in a way that doing that in software never really felt*. Participant 8 interview 2020.

Generating Difficulty and Problem Solving

Some participants expressed a desire to avoid things being ‘too easy’ and framed aspects of their use of their modular instrument as a way of generating processes that required a greater level of labour, skill, attention or time to achieve desired results (Participants 11, 13).

> *So often I don't like things... that just work really nicely. I kind of choose things that I have to wrangle a little bit.* Participant 11 interview 2020.

Similarly, other participants positively described their experiences of working with their modular synthesiser as a process of problem generation and problem solving (Participants 1, 5).

> *I like engineering and finding out solutions to problems. And I suppose the synthesiser is always a problem because, with a guitar, a lot of the problem has been solved, but whereas with a synthesiser it's like all exposed, it's ready to be a problem that you can think about… I've had a lot of synthesisers, but once I started with modular… because everything's changeable and patchable, it's a problem that never ends.* Participant 5 interview 2020.

Immediacy and Flow State

Participants described an experience of immediacy when working with their modular instruments, noting that the real-time nature of the system allowed them to hear changes as they patched and made changes to the system one connection at a time. (Participants 1, 6, 11,12, 13, 16)

> *I've gone very much in this more immediate, real-time direction with music where I'm, I'm far more interested in things that you can instantly start applying, you know, uh, concepts to instead of just having this long planning stage leading into eventually making sound. And I find that the immediacy of the modulars was made more appealing to me.* Participant 6 interview 2020.

Some participants used the term *flow state* to describe their experiences of being engaged and in the moment while patching their instrument and noted this as being desirable and a key reason they enjoy working with their instrument (Participants 5, 16, 18).

Limitations

In comparison to software-based approaches, any modular synthesiser instrument is limited to the capabilities afforded by the modules installed. Some participants saw this as a key positive aspect of their instruments, as the limited nature of the instrument encourages them to focus and deeply explore particular ideas with less distraction (Participants 5, 21). It seems likely that this aspect of the modular instrument contributes to the generation of problems as the musician finds workaround to the limitations they encounter in the

instrument. The limitation aspect may also assist in maintaining a flow state as there are fewer options on hand that may distract from the process at hand.

Habitual Patching

One participant noted their own tendency to form habits in the way they patched their instrument and linked this to the physicality of the patching process (Participant 2). In response to this they would try to remain aware of repetition in their approaches and deliberately work against them so as to disrupt their own habits and create unexpected results.

Iteration and Repetitive Use of a Patch

In contrast, some participants described particular processes and concepts that they would repetitively return to in their modular synthesiser, performing and practising them over several years (Participants 1, 5, 6, and 11). Participants' modular synthesisers would be designed towards the realisation of the concept, becoming highly specialised instruments over time as more modules are added and swapped over time.

Learning from Modular

Some participants related that the process of patching and using their modular instruments had helped them to learn and understand the principles of synthesis and signal processing on a level they did not previously through their use of computers or fixed architecture instruments (Participants 2, 8, 11, 12).

> *It really made me start to realise, you know, more of the kind of elemental principles of synthesis and things like that, which I still don't understand completely, but, you know, on a more intuitive level, I really began to understand signal and signal processing.* Participant 12 interview 2020.

> *I wasn't really thinking about the... subtractive synthesis rationale, you know, this is a more complex waveform, it's going to work better in a filter… I hadn't been thinking about that really. So, I think… what the modular has done for me is really taught me a lot about the fundamentals of synthesis that I just didn't care about in my other ways of working.* Participant 8 interview 2020.

Improvisation, Collaboration and Interface for Performance

In addition to the implications of physical patching, composing with the modular also impacts other aspects of music performance. Some participants viewed the modular instrument as a means to perform live, a way of improving their live practice, or a strategy to encourage improvisation in their practice (Participants 8, 11, 12, 18, 21). Not all the participants work with their modular instruments in a live setting, but those that do often reflected upon this process both as solo performers and in collaborative group performances.

Live Performance

The modular instrument was described as being more enjoyable both for the performer and audience due to its tangible, physical and hands-on nature (Participant 3). A participant also reported that using and practising with their modular synthesiser as an instrument enabled them to take their compositional process into a live performance setting (Participant 13).

> …*using the modular as an instrument and practising with it as an instrument, which is also handy if you ever want to, if you do want to perform live.* Participant 13 interview 2020.

Some participants compared their use of their instrument in a live setting to experiences of performing or watching performances of laptop-based practices, describing the laptop-based experiences as playing back or presenting existing material and situating the modular synthesiser in a live setting as a more involved, less predetermined and higher risk undertaking (Participants 3, 8, 13).

> *I just think that for me personally, I like to be doing something when I'm performing. And also I get a little bit bored if there isn't a risk, so I wouldn't want to determine something so much that I wasn't kind of interested in what would happen.* Participant 8 interview 2020.

One participant noted difficulties associated with performing live with a modular synthesiser, such as when their practice is not fully embedded in just the modular instrument and/or when their intention is to perform specific compositions rather than completely improvise (Participant 18).

> *It was like a real, like existential crisis for my modular... coming up against that realisation that it's not necessarily the best or easiest instrument to perform with.*

> *Particularly if you're interested in playing in a way where the music is not structured around the way that modular synth works.* Participant 18 interview 2020.

Improvisation

Most participants demonstrated varying degrees of improvisation in their use of the modular in the research interviews. Some participants viewed the modular instrument as a tool that allowed for greater agency for improvised actions, in comparison to other modes of electronic music production (Participants 9, 10, 17, 19, 21).

> *I guess that's the way that I sort of use it is as this kind of improvisational, uh, tool, um, in the studio, like jamming and then recording that as I go and then sometimes trying to keep things as simple as possible, in a sense. I was used to kind of work recording and writing sort of very heavily manicured forms of dance music and it was, I felt, very detached from the actual kind of process of improvising in music.* Participant 19 interview 2020.

Collaborating

While the modular instrument seems to lend itself to improvisation, participants found it challenging to work in a group- or duo-based live setting, particularly when the other musicians were using more traditional instruments or voice (Participants 1, 11, 18). Some participants went to significant lengths to customise their instrument so that they can respond quickly or more intuitively to other musicians (Participants 1, 11, 18). In some instances they undertook negotiation with the other musicians so that they were forewarned of some of the structures and timbres likely to emanate from the modular instrument (Participants 1, 11).

Performance Interface

Some participants emphasised the hands-on nature of the instrument and the physicality of the voltage control connections as encouraging and supporting their ability to perform (Participants 5, 10, 21). In contrast to those who welcomed the transparency of the patching paradigm, other participants noted challenges in relation to the interface of their modular instrument in a live or improvised context due to the small size of the dials and faders and impediment of patch leads covering the interface (Participants 1, 5, 8). The broad scale of the voltage control signals and parameters combined with the small scale of the interface also seemed to form an impediment to some undertaking nuanced and subtle variations (Participant 1).

Some participants whose practice emphasises collaborative and improvised performance had utilised a range of modules specifically as control interfaces, including arcade-style buttons, pressure sensors, breath controllers, and ribbon controllers. The use of controllers enabled shifting particular controls outside of the main modular instrument to enable easier access, situating particular controls together, and the use of physically larger or pressure based controllers to enable more nuanced or somatic control.

Case Study: Improvisation Performance-Oriented Interface

Participant 11 described their use of their modular synthesiser for live performance, often working with other musicians to create improvised music. They prioritised the ability for their instrument to produce multiple concurrent voices of audio, each with a distinct timbre, and controlled these via a touch pad module (Tetrapad, n.d.). This enabled them to quickly react and respond to other performers using the pressure sensitivity of the touch pads to expressively modulate various parameters, including the volume of the sounds produced.

Each of the voices or sound sources is a distinct timbre: a crackling hiss produced by a white noise source being fed into a crude VCA circuit, a wavefolder being fed back upon itself to produce a complex and unpredictable howl, a digital reverb with a long tail of delays, and a physical modelling oscillator being excited by a contact microphone. Over the course of a performance each source would be adjusted to create shifts in timbre.

The participant described an approach where they would first identify sound sources and then work out how it would be controlled through performance.

> *I like building those, those little kind of, processes first and then going: okay, how might this work as something that I control as an instrument? And that's when I'll do something like… you know, hands-on control over the volume.* Participant 11, 2020.

The approach taken by the participant privileges physical interaction with their instrument to effect changes, enabling them to perform in a very responsive way, utilising physical pressure via the touch pad module to enact nuanced and expressive control. Alongside this is the use of a contact microphone, which would be tapped, rubbed or slapped during a performance, which emphasised a physicality that is visible to the audience. The participant contrasted this approach from other compositional modes that they utilise, noting significant differences in comparison to their use of their other modular synthesiser that is based upon Serge synthesiser designs, which they

would use in a more generative fashion with much less reliance upon physical expression.

Timbre

The possibilities for timbral qualities using their modular synthesisers were described as limitless, malleable, and extending far beyond those of a traditional subtractive synthesiser architecture (Participants 6, 12, 15, 19). The flexible interchange of audio signals and control signals within the Eurorack standard or the ability of many modules to perform in either role was noted as contributing to the generation of timbre possibilities (Participant 19). The contemporary Eurorack standard was seen as having greatly expanded timbre generation possibilities beyond earlier modular instruments (Participants 6, 19).

Challenges of Modular Composition

Composing with the modular instrument presents specific challenges. Participants described aspects of their experiences using their modular instruments as challenging in terms of their instability in pitch and timing and the lack of ability to save and recall patches or settings. Many of these problems were the impetus for the development of the digital systems that replaced analog modular systems in the 1980s and it is therefore unsurprising that the rediscovery of the modular should also entail a rediscovery of these issues.

Instabilities and Slippage

Some participants described the modular instrument as being unstable, with patches sounding or performing differently from day to day, slipping in and out of sync with other instruments, and as being unable to save and recall a particular state (Participants 4, 6, 8 12). In these particular cases the instabilities were seen as largely positive aspects of their experiences.

> *I could see that patch and make exactly the same... choices and it would yield completely different music. Or at least it would be different melodies that the randomness of it would be slightly off. Again, with the analogue drift, it would be slightly different. Maybe there's something great in that lack of repeatability, you know, that it's embracing what it is that's inherently analog about it to make completely different experiences from time to time.* Participant 6 interview 2020.

No Save

The inherent inability for a modular synthesiser to save and recall its configuration presented a challenge to some participants, particularly when their usual workflow was predominantly software-based (Participants 12, 15, 18). For those who create music professionally for theatre or film this limitation was particularly critical as edits and changes to the broader production may require rerecording sections from the modular synthesiser (Participants 12, 15). Participants described workarounds, shifting their practice to accommodate the instruments limitations. One participant records large amounts of audio with the intention of editing and incorporating the recording into compositions later (Participant 12). Another participant had invested in a range of digital modules with the ability to save presets to assist them to perform specific pieces or replicate particular approaches (Participant 18).

Pitch

Using a modular synthesiser, oscillators must first be tuned to each other or an external source in order to create chromatic or other musical scales. One participant noted difficulties when incorporating melodic material into their improvised compositions due to tuning issues, but they also described the use of ‘explicit’, defined pitches as seeming starkly out of place when combined with the rhythmic materials they had already constructed (Participant 17).

Timing

One participant found the timing of analog step sequencers to fall out of sync with other equipment, making it difficult to rely on them for syncopated material (Participant 12).

Lost in Minutiae

One participant described experiences of their instrument where they became very focussed upon small details or sound design and lost sight of a larger scale composition.

> *Especially when I was first working with modular systems… I would get into the minutia of it so much that I would really lose sight of the larger sort of compositional gesture that was going on. And so I would have these moments of really great, at least to my ears, really great sound production, really great synthesis, but as a larger sort of form, you know, nothing really, you know, it could be ‘Pop Goes the Weasel’ for all I know*. Participant 2 interview 2020.

Summary of Composing with the Modular Instrument

A range of descriptive themes were constructed in relation to participants' experiences of composing with their modular synthesiser. While the experiences and intentions are diverse, some aspects can be correlated to support broader conceptualisations, such as a relinquishing of compositional control to complex systems and indeterministic processes, and an emphasis upon the performability or instrumentality of their device. These and other concepts will be further explored and synthesised in the Discussion chapter.

Curation and Configuration of the Modular Instrument

Most participants worked predominantly with the Eurorack modular synthesiser standard and were engaged in processes of selecting modules, designing and configuring their instruments. Participants considered these decisions very carefully, balancing the possibilities of a new module against its cost and the amount of space available in their instrument. There were divergent views about where the system should facilitate diversity or specificity and in some cases this choice was driven by a kind of ideology. One expression of a 'modular ideology' was the choice between analog and digital sub-systems. Another aspect of curation and configuration was the opportunity for DIY module development, either from kits or as a design process. These aspects of modular synthesiser use are broadly visible in the wider community and reveal another way in which this technology affects musical practice.

A Curated Environment

All participants interviewed who use a Eurorack format modular instrument described and displayed a great interest in the configuration of their instrument, describing decisions they had made, or were in the process of making, relating to their curation of the instrument (Participants 1, 2, 3, 5, 6, 8, 9 10, 11, 13, 14, 16, 17, 18, 19).

> *So, with modular, the beaut thing is you don't, unlike a normal synthesiser that you get and you set, the design is done and you put up with that or you bring in something else, but here, each module is a separate thing and... someone's made it and they've had the thought and then they've got inputs and outputs.* Participant 5 interview 2020.

All participants involved in this process of curating their instrument seemed to consider their decisions seriously, factoring in a range of issues in the process including cost, size,

functionality in relation to their intentions, and usability (Participants 1, 2, 3, 5, 6, 8, 9 10, 11, 13, 14, 16, 17, 18, 19).

> *This is a system that I've built intentionally with a purpose… there's a financial cost to me actually buying a new module. So it brings a sense of gravity to that, just because I have to spend money to do it. But there's also a space requirement and there's also, you know, a need requirement. Like, will this actually help me achieve my creative goals? So there's all these kinds of competing, um, things that, uh, come to a decision when creating a modular synthesiser that's going to, you know, meet the needs of your creative desires.* Participant 17 interview 2020.

Module Acquisition

Participants described a range of strategies in relation to the decision to buy a new module. Some participants felt wary of the potential of their instruments to be endlessly expandable forming a 'bottomless pit' (Participants 2, 5, 17, 18). Some participants also expressed a concern that the acquisition of modules can become the hobby itself, where collecting becomes the focus rather than constructing a means to make music (Participants 2, 8).

> *I think there's something within the modular culture, there's sort of a... hobbyist kind of toy train, collector-style-like mentality, that I think people can get into where you're like... 'Oh, like there's a new caboose on the market'.* Participant 2 interview 2020.

Participants sometimes used the size of their rack or case as a way of limiting the number of modules, forcing themselves to sell a module in order to fit in a new one in (Participants 2, 5, 18).

> J*ust buy a really small box... if it doesn't fit in this, it's not in. And I want a performance thing – I want something I can carry around and I want to have a voice that's limited.* Participant 5 interview 2020.

Participants also described resisting the urge to purchase new modules as a discipline that also helps them to get the most out of the modules they do have, thinking laterally to see what other possibilities might be achieved with the same instrument configuration (Participants 2, 11, 20).

Some participants described their own financial circumstances as not allowing for new modules or larger instruments (Participants 9, 18, 20). One participant had decided to only use modules from Doepfer as they were cheaper than some other brands, and they also

found the consistency of the module aesthetic designs satisfying (Participant 20). Other participants focussed upon building DIY module designs as this was a significantly cheaper approach (Participants 9, 18).

Building an Instrument

Some participants conceptualised their modular synthesiser as a stand-alone instrument that the participant would then perform and record with (Participants 5, 11, 13). In this case, the instrument is not intended to be controlled externally, or necessarily function as part of a larger collection of equipment.

> *I kind of view it more like an instrument in and of itself. I don't, I don't often integrate it with the computer that much. I mainly just use the computer to record it, mix or whatever.* Participant 11 interview 2020.

Participants emphasised the word *instrument*, associating it with real-time performance and accentuating a stability in the configuration of their modular synthesiser that enables them to practise and perform live (Participants 5, 11, 13).

> *That's the most interesting thing for me, using the modular as an instrument and practising with it as an instrument, which is also handy if you ever want to... perform live. Because what I tend to do when I perform live is build a specific setup and decide which modules I'm putting in. And then I'll practise with that as an instrument in itself and not move outside that particular small subset of modules that I've put together that work together in a particular way.* Participant 13 interview 2020.

Modular as Unified Studio

Some participants described their approach to making music as 'studio as instrument', citing the recording practices of the Beatles and dub reggae techniques where real-time performative approaches are applied to mixing desks, audio processing and manipulation of recorded material (Participants 13, 17). In these cases, the modular instrument was configured and utilised as a studio space with embedded mixing, effects, recording and playback capabilities.

> *The paradigm that the Beatles really worked with… the studio as, as the instrument. I really took that on and saw that as the kind of the modern way to make music, interesting music. To me, at least, I think that the studio is the instrument. And so, for*

> *me, modular is a perfect exemplar of this… it's the way to actually create something that is so embedded in, in everything that you do.* Participant 17 interview 2020.

One participant described working with acoustic sound sources in real time with their modular instrument, processing the sounds but also deriving envelope and gate signals from the acoustic sound (Participant 13 interview 2020).

> *And so you'd be making the sound, however you make it, and it's being manipulated at the same time and you're modifying – what you're doing with the acoustic thing in relation to what's happening in the modular, kind of, is one big process.* Participant 13 interview 2020.

Mixer in the Modular Instrument

A number of participants highlighted their use of dedicated audio mixer modules with multiple channels, faders and effect sends in their modular instrument (Participants 5, 11, 13, 17). Participants described approaches that relied upon the mixer as a performance tool to introduce and cut off specific voices using a hands-on interface (Participants 5, 11, 13, 17). This approach was then augmented by possibilities for various generated CV signals to automate components of the mixer module, including levels, panning, and effect sends (Participants 5, 11, 13, 17).

A Versatile Synthesiser Voice

One participant was concerned with limiting their investment in Eurorack modular, and primarily motivated to use their modular as a traditional fixed architecture-style synthesiser voice, described their strategy of including multiple filters in their instrument to simulate a range of classic synthesiser voices.

> *So, I figured I get a synth's worth of modules plus a whole row of different filters. It would sound like if I've got, say, six different filters that I've got six different synthesisers, but it's just the same one. So it's like my cheating thing to make it sound like I've got more synths than I actually have, you just have all the filters of each.* Participant 20 interview 2020.

This participant exclusively sequences the instrument using MIDI from a computer and builds layers of apparent polyphony by rerecording sequences multiple times.

Versatility and Specificity

Two participants delineated between module designs they considered to be versatile and others they found to have a specific use with limited possibilities (Participants 13, 15). These participants connected the use of highly specialised modules to a loss of agency for themselves (Participants 13, 15).

> *I prefer modules that are not just one trick ponies, that you basically buy for a particular purpose and just use it for that purpose. And there are a lot out there, but I find that you're locked into, uh, a particular way of operating with that module that is more what the designer has decided for you to do with it rather than what you want to do it with it, or what you can find to do with it yourself.* Participant 13 interview 2020.

A participant made a comparison between contemporary module designs that perform specialised functions and synthesiser designer Serge Tcherepnin's design philosophy.

> *I think the art of a lot of current modular stuff is in the design of the modules. These modules that are designed to create specific sounds or designed to be used in very specific ways, choices that have been made by the module designers. I think that Serge wanted to not make these choices for you. I think he wanted you to make these choices for yourself. And I liked that.* Participant 15 interview 2020.

Designer Ideology

Expanding on this, some participants described an awareness of a relationship between themselves and synthesiser or module designers, experienced through their use of instruments and modules (Participants 2, 5, 6, 13, 15, 17). These participants described developing an understanding of the designer's ideology through use of the instrument or module and its impact upon their own compositional process (Participants 2, 5, 6, 13, 15, 17). The compositional ideology of designers of discrete modular systems such as Donald Buchla or Serge Tcherepnin were particularly singled out by some participants who had used these systems (Participants 1, 2, 4, 11, 15, 21).

> *I ended up at EMS* (Elektronmusikstudion EMS, n.d.) *in Stockholm using their Buchla, and working with the Serge system at Bard* (Bard College, n.d.) *and stuff. And so, like, started to get involved... started to understand that each system that you worked with was sort of an engagement with the… production ideology of the creator... the designer of those systems. And so it became a very interesting way of thinking through… different kinds of compositional logic systems and how they're sort of*

> *inspired by one's interaction with a piece of equipment or a system.* Participant 2 interview 2020.

Module Designs Elicit New Approaches

One participant described being drawn in new compositional directions by the capabilities of a module they had bought for a different purpose (Participant 6).

> *I ended up making music with an instrument like that that I would never make. I would never seek out those kinds of sounds, but because I'm attracted to one aspect of what it is that it does, I then am tempted to incorporate… all of the other things that it does into music without really seeking them out.* Participant 6 interview 2020.

Digital in the Modular

A number of participants distinguished and reflected upon their experiences of using modules with overtly digital characteristics, including screens, menu systems, the ability to record or playback audio, or flexible DSP-based functions (Participants 1, 2, 6, 8, 11, 13, 16, 17, 18).

Comparison to Analog

The situating of modules using all-analog circuits alongside overtly digital modules in the same modular instrument afforded participants the opportunity to compare their experiences. One participant described processes of setting up digital modules in order to be able to patch them to the rest of the system and perform or compose (Participant 1).

> *I guess those two approaches to me are very, very different. You know, one, I have to sit all day and think and, and, and really dial up all the, the right, the right stuff so that I can explore in this digital domain and be relatively free in doing it. With the Serge it's like plug, plug, plug… when I go to that system, I don't have any kind of preparation. I can just patch, patch, patch, patch… very different feeling. I'm not setting up a complex but satisfying environment that takes a lot of one head space so that then later on I can defer that headspace; when I'm doing the Serge, the headspace, I immediately hop inside it and I'm there.* Participant 1 interview 2020.

The same participant differentiated between the type of problem solving they typically engage with using their analog modules and issues they have to resolve when using their digital modules (Participant 1).

> *And you're just kind of solving problems. That's the feeling of that and the problems aren't, how can I trim... all these WAV files? And then where's my SD card reader? And, you know, it's just, how do I make this slew into an oscillator? Oh, that's right. You know, those kinds of fun problems.* Participant 1 interview 2020.

Digital Versatility

Some participants who used overtly digital modules described the possibilities enabled by recallable presets or playback of samples as bringing a particular versatility to their modular instrument. One participant described using digital modules to quickly shift between sounds to enable radical shifts in a performance or composition.

> *You can change quickly in terms of all right, here's the sound of the ocean, now we're going to switch to a kick with a snare, that bit of reverb up there. Okay. Now let's bring in a beat over here. Okay. Let's bring in chords from a synth here. Let's take all that out. You have a lot of freedom to just shift quickly between very large, different styles of sound.* Participant 1 interview 2020.

Another participant described a process where the functionality of a complex digital module could be saved and recalled at will to enable a range of discrete compositional uses within a broader patch.

> *I think for me, the, what I like about the recall is simply that, uh, there can be a certain amount of, um, functionality and complexity set and kind of kept that can be reengaged with, but it sort of freezes as an instrument… And I think with the 301* (Orthogonal Devices, n.d.) *I have certain patches within it that are just that, you know, it's not about… continuing to evolve every time, how they function each time I use them. I just know that they're a tool that's there and ready to be engaged with.* Participant 2 interview 2020.

One participant noted the expandible and modifiable nature of digitally based modules and connected this aspect of digital modules to affordability and access (Participant 18).

> *Some people get really into vacuum tubes… I just don't really want to worry about that. I don't, I don't want to care about that cos it's elitist and inaccessible to me. But if I'm creating music in a DSP environment, it's like limitless. This is what I want, my practice to continually expand. So to me, learning those skills is like investing in my future to keep growing my skills*. Participant 18 interview 2020.

Menu Diving and Screens

The use of menu systems to access settings or parameters was noted by participants as particularly specific to digitally based modules, alongside the inclusion of small LCD screens as a component of the module's interface. Some participants expressed a reluctance to engage with modules that relied upon a screen or required a level of 'menu diving' to operate (Participants 5, 11, 16).

> *I've got this Zadar* (Xaoc Devices, n.d.) *here, which is great as an envelope generator, but it's a bit, it's the menu diving… it doesn't even take that much… but it's a digital module, so I don't end up using it that much just cos... I don't want to look at a screen, so I don't use it that much*. Participant 11 interview 2020.

New Approaches to Digital Synthesis

Participants also described and demonstrated their use of modules that offer typically digital synthesis methods such as wavetable or frequency modulation, opening these synthesis techniques up to modulation via CV. These participants noted the immediacy of utilising CV to modulate these synthesis engines, and the possibilities for dynamic timbre changes not encountered in non-modular implementation of these synthesis approaches (Participants 8, 17).

Replacing or Avoiding Using a Computer

One participant related a particular work that they regularly perform had previously relied upon them also utilising Max software alongside their modular instrument to play back samples and detect transients. Since incorporating a digital sampler into their modular they had not needed to utilise their computer to perform the piece but instead were able to perform it solely within the modular instrument (Participant 6).

> *Now I just use the Rossum* (Assimil8or, 2016) *with... [a] stochastic function generator, which also has comparators in every channel, so you can kind of, like, easily do the transient detection in hardware. And then I was like, great. I haven't sat here really thinking that I needed to boot up Max to solve a problem within the synthesiser in a long time*. Participant 6 interview 2020.

Another participant expressed a desire to have effects like delay and reverb as modules in their case so that they would not require a computer to generate or apply these effects in a live context (Participant 3).

Summary of Digital in the Modular

Participants noted their own awareness of their use of digital modules in their modular instruments, delineating between these experiences and their experiences of analog based, or perhaps analog presenting modules.

DIY Building Modules and Open-Source Designs

The DIY and kit-based approach goes back to the early days of the modular synthesiser with kits from companies such as PAiA Electronics (“About PAiA,” n.d.) having been marketed from the early 1970s. Some participants had experiences of building modules using DIY kits and reflected upon these activities (Participants 6, 9, 13, 18).

Cost and Access

The relatively lower cost of building DIY modules was identified as an initial attractor to these undertakings and modular synthesisers more generally (Participants 9, 18).

> *One of the only things I'd heard about modular was that it was really expensive, and I was kinda like, oh, that doesn't seem possible for me, um, to buy things new, but maybe I can build things myself. Maybe that'd be cheaper. Maybe that'd make it possible for me.* Participant 18 interview 2020.

The same participant also noted the time-consuming nature of building modules themselves and the risk of modules not working correctly due to mistakes or issues with components (Participant 18).

> *I did a bit of DIYing. Um, after a while I kind of realised that, um, it was... not so much cheaper that it was so worth putting all these extra hours in and risking it not working.* Participant 18 interview 2020.

Learning Electronics

One participant described building DIY modules as an opportunity to learn how electronics work and develop their skills in soldering.

> *I really liked the DIY stuff that I could sort of build myself, um, and that was kind of a challenge for me, because I didn't know anything about electronics, so it was like an opportunity to learn really cool stuff.* Participant 9 interview 2020.

Customising Existing DIY Designs

The possibilities for modifying DIY module designs as part of the building process was noted by one participant as a key component of their interest in building modules themselves.

> *The best thing about building, um, modules yourself is that if you built a, or you're building it and you decide, well, I like 90% of what this module does, but I wish it did this, or it did this this way. Then if you have a bit of basic electronics knowledge, then you can modify it or change it up while you're building it, um, to, um, to perform the function that you want more effectively.* Participant 13 interview 2020.

Open-Source Module Designs

One participant related an interest in open-source module designs and these being a key component to them engaging with modular synthesis (Participant 18).

> *I saw this other modular rig and I thought, okay, maybe I want to try and explore some other things, and he was using his racks [that] had a Rings and Clouds* (Mutable Instruments | Home, n.d.) *in it. And an Ornament and Crime* (Ornament & Crime, n.d.)*. Um, I was really interested in open-source stuff. I was a really nerdy kid and growing up as a teenager, like I was really kind of into that whole open source movement, um, and, like, hackable things and DIY.* Participant 18 interview 2020.

Therapeutic Practice

One participant described the process of building modules as being a therapeutic or peaceful experience that is time consuming but motivated by the possibilities of the new module at the end (Participant 6).

> *I find it therapeutic when I build something… You know, it's a real peaceful process. It's time consuming, but it's very therapeutic I think to have that… at the end of the thing is going to be this beautiful thing that makes sound so I'm more focused on it.* Participant 6 interview 2020.

Unlike other instruments, the modular is one that can be assembled to reflect the interests or motivations of the musician, or that reflects a kind of musical ideology of the designer. Furthermore, the modular allows musicians to focus elements of a studio-based practice into a single device.

Community and Broader Interactions

Some participants noted the importance of interactions with others in relation to their interest in modular synthesisers (Participants 1, 5, 6, 9, 13, 18). These interactions occurred in a range of situations, including online, in person, through teaching, and with modular designers. The current popularity of modular synthesisers was noted by one participant as resulting in a diverse discourse and array of possible interactions (Participant 5).

> *It's a great time. Like the manufacturers, there's so many different people trying out different things, so there's a lot of interesting work going on and there's community and there's discussion and there's critique and lots to try and swap in and out, and people trying to solve the problem in different ways. And people doing very different things from full art stuff to full commercial pop music and everything in between.* Participant 5 interview 2020.

Connecting with other People

Interactions with communities and connecting with other musicians who work with modular synthesisers were described by some participants as being inspiring for their own practice and enabling exchange of ideas and possibilities for collaboration and skill sharing (Participants 6, 9, 13).

> *The modular… opened up a new world, and also because... it was becoming such a popular thing. There were so many other people getting into it and also there was a lot of opportunities to network with other people and just a very inspiring time.* Participant 13 interview 2020.

> *It's become really interesting recently and I'm getting a lot of commissions to go and travel to places where there's already that community and I want to... get involved and see what they're up to and what ideas they have, and then do something based on that... It's a nice time, a lot of fruitful collaboration based on, you know, these very ultra specialised ways of looking at music and what problems can be solved… that's been pretty incredible.* Participant 6 interview 2020.

One participant particularly noted the importance of community in relation to their practice of building DIY modules (Participant 9)

> *I guess I was always interested in it, but I didn't really know how to really access anything, anybody that could really teach me what to do. And I didn't have a lot of*

> *money, so it was kind of easier, you know, spending $50 a month, um, building something and then having people... giving me access to a community that could help me and... mentor me.* Participant 9 interview 2020.

Web-Based Resources

One participant described the rich array of resources available on the internet in relation to modular synthesisers and specific modules, noting a relationship between this information and the process of choosing modules for their own instrument (Participant 16).

> *All of those manuals, all that knowledge, [for] each new module that comes out, there's YouTube videos, there's forum posts, there's this whole wealth of knowledge around them. And it's something that, that cycling of information kind of, is reified in, in some way in the, in the, in the machine...That's what guides how you build these systems.* Participant 1 interview 2020.

Teaching Modular

One participant leads workshops for people new to modular synths. They approach this by first introducing them to a semi-modular instrument, encouraging them to start by intervening in the synthesiser architecture via patching and then introducing modular instruments. The modular instrument they first introduce them to is a Doepfer (Doepfer A-100, n.d.) only system, this is chosen due to the consistency of the design and clear labelling used in Doepfer module designs (Participant 16).

> *Give someone access to a semi-modular and then say, all right, here's a whole bunch of cables, go nuts, see what works, see what doesn't work. See what you hate and then go from there and then say, okay, so do you like doing that? Do you like the act of breaking it down and changing its parts? Okay. Yes. Great. Go and use that... big, Doepfer system over there. So why don't you go and use that because the parts are labelled really cleanly. It's… four oscillators and x amount of VCAs and filters. So now try and connect them up from the knowledge that you gained from the semi-modular and see how you go.* Participant 16 interview 2020.

The participant explained that the complexity of a customised Eurorack system with components from a variety of manufacturers including highly specialised or esoteric modules would make for a difficult instrument for a new user to understand (Participant 16).

> *I don't think you can necessarily sit someone down in front of like 6U you have [of] customised Eurorack and… you know, you've got some of these more esoteric modules, like the Telharmonic* (Make Noise Co. | tELHARMONIC, n.d.) *or the granular stuff, or even a MATHS* (Make Noise Co. | MATHS, n.d.)*. And like, I mean, how do you explain MATHS to someone as a module?* Participant 16 interview 2020.

Gender and Modular Synthesisers

Issues and ideas relating to gender were noted by some participants (Participants 10, 14, 15). One participant recounted being initially turned off from exploring modular synthesisers due to interactions she had experienced at a male-dominated modular synthesiser meet, where the organiser expressed an ambivalence regarding the inclusion of female musicians in the scene (Participant 14).

Another participant explained that they had experienced people through the modular synthesiser community who were supportive and active in making the community more inclusive and that these one-on-one interactions were a stark contrast to their experiences in online forums (Participant 10).

> *I think there are like a lot of politically clued-in people who do actually care about supporting women in the scene. And I think it's really unfortunate, but obviously if you hang out in forums and stuff, you just going to be met with like, I don't know, I suppose it's just 21-year-old boys… if you're looking, if you're looking for solidarity, a synth forum probably isn't the right place to look, but if you approach people with the right ethos, one-on-one, particularly people who run meets and who run synth festivals and stuff, you're going to find some amazing people.* Participant 10 interview 2020.

The same participant runs workshops for primary school-aged girls, introducing them to electronic music making and synthesisers. These activities are designed to encourage more women to be involved in electronic music.

> *I think that's just part of my wish to kind of keep bringing girls on board with this stuff… I sort of think it's important to kind of not shut the door behind you.* Participant 10 interview 2020.

One participant described their initial involvement in modular synthesisers in the 1970s, noting that a key attractor for them and other women to compose electronic music using modular synthesisers was to circumvent barriers to women composers.

> *I think at that point, the idea of whether or not a girl could even compose music was still a topic of conversation as if perhaps, you know, putting pen to paper was like somehow required being a guy somehow… I think it appealed to some women early on, because you could bring a musical idea to fruition without having to convince an orchestra to play it, without having to convince… anybody to take you seriously. So I think that that's my personal theory about why some women took to it very early on.* Participant 15 interview 2020.

Comparisons of Modular

In the process of describing their experiences of working with modular synthesisers, some participants compared their experiences to other approaches of making music with software or non-modular hardware.

Compared to Software

Some participants made comparisons between their experiences using their modular instrument and working with software (Participants 2, 3, 4, 6, 12, 13, 18). One participant described their use of their modular as a strategy to avoid using a computer as their primary composition device (Participant 13).

> *So then the modular synth has become, as it's evolved, a way of doing that outside the computer, which is, uh, which was very refreshing because I was finding working in a computer-related field and looking at the computer screen all the day, and then trying to make music with or make sound with it. …it wasn't really inspiring me so much.* Participant 13 interview 2020.

Another participant described their experiences of only using a computer to perform as not being interesting for themselves or the audience and situated their use of their modular instrument as strategy to make the process of performing live more dynamic and performative (Participant 3).

> *And it's like, you really want people to appreciate your music and you want to perform live. But if you're just playing the music to hear it loud and kind of sitting there, maybe doing some effects with the mouse over something, you know, that's not interesting to see. So that's why I really wanted to do the hands-on stuff. It's more fun for me, more fun for everybody to see.* Participant 3 interview 2020.

One participant described their experiences of composing with software as being orientated to quantised timing and described their experiences with a Buchla 200 (Buchla 200 Series | Vintage Synth Explorer, n.d.) Series modular as operating more freely outside of a grid (Participant 4).

> *I think in a way when you're working with software, it naturally forces you to quantise. But, um, because… I haven't really done any musical training or anything like that, so my brain doesn't really work that way anyway. So, like, even when I'm writing, um, a beat, a straight-ahead beat in Ableton* (Ableton Live Website, n.d.)*, I'll kind of, like, just move the MIDI around until it sounds right… I think it's like a similar thing that I like about this, where it's like, you can just hear out what sounds right... machines like this lend themselves so much to that kind of practice.* Participant 4 interview 2020.

Another participant reflected upon their previous intentions of avoiding using a computer to compose (going DAWless) critiquing this as being irrational or dogmatic.

> *It doesn't matter to me whether it's in Ableton or not, um, like, it's almost like being like, I feel like I got on this point of, you know, trying to go DAWless or something like that. It's a funny mindset going into it... and I'm trying to... unpack whether it's irrational or just dogmatic.* Participant 18 interview 2020.

Comparison to Max

Some participants made specific comparisons between their experiences using a modular synthesiser and their experiences of using Max (Cycling ’74, n.d.) software to build instruments.

One participant described the skills, knowledge and energy required to build instruments in Max as a creative pursuit in itself. They situated their use of the modular synthesiser as a deliberate strategy to work with greater limitations in a more focussed environment (Participant 2).

> *I don't want to be lost in that aspect of production and not to be hearing what I'm doing and that's, you know, like that's why... I think Max and Supercollider are... all obviously so awesome, so amazing. But I realised pretty early on that the people who are really great at building in those platforms, that's a big part of their art making… it takes tons of creative energy to be a designer in that way and… a builder in that way.* Participant 2 interview 2020.

Another participant noted the hands-on nature of patching with a modular instrument as a key reason for changing their practice from being Max-based to the physicality of a modular synthesiser. They particularly noted that the physicality of the modular instrument assisted them in knowing and remembering the functions of its components (Participant 3).

> *I'm not really that [interested in Max], I was interested in it... when I saw the modular synthesizer at NAMM at the NAMM convention, that's when I really knew that, uh, it made more sense to patch with your hands instead of with the mouse for me.* Participant 3 interview 2020.

One participant noted that their modular instrument as an intentionally curated environment encourages them to persist with particular approaches or processes in comparison to the limitless nature of a software environment like Max, where components can be readily replaced or duplicated (Participant 17).

> *Digital environments like Max/MSP, topographic programming environments that allow you to create all kinds of software to make music, don't necessitate that same kind of gravity and intention that you get with a modular synthesiser. Because I've had to make a very active decision about everything I've done here and... I'm not very readily going to get rid of any of it. I have to work with it to kind of rinse out everything from it before I can really… say to myself, yeah, okay, cool, I'm happy to move on from this. Whereas Max, I'll create a million variations of a single patch to try and arrive… at the right answer to a problem.* Participant 17 interview 2020.

One participant described their shift from primarily using Max to a modular synthesiser being driven by their experiences of working with Max as onerous and repetitive (Participant 8).

> *I think I just reached a point where I wanted to stop using Max a bit. I found that the things that I was doing with Max were becoming really onerous from a programming point of view, like, it was just taking a long time to patch, a lot of repetitive processes and things. And I think I'd lost a bit of the exploratory fun that I'd had learning Max and, and learning what it can do.* Participant 8 interview 2020.

Another participant noted that their work with Max and their modular synthesiser are very separate processes, describing experiences of Max as being ‘right brained’ and their experiences with their modular instrument as a more aesthetic and experiential process.

> *I mean, obviously I'd make music that's completely separate from the module music in Max, but the incorporation of the two these days is almost non-existent. I mean, I really*

> *rarely do it….things were recorded, then sent into the computer and then I use plugins and things to mix and master and that kind of thing. But um, yeah, it's really, it's as stand-alone as it ever has been. I guess. It's really not… There's no healthy intermingling between the two things. I have a totally, like, 'this is a right-brain thing, this is a left-brain thing' in my mind… Max is the right brain – computational, analytical – and then the modular's totally aesthetic and you know, more kind of experiential. That's, that's the way I've always seen it.* Participant 6 interview 2020.

In comparing their experiences of patching with their modular and building an instrument in Max, one participant noted a sense of tangibility in working with voltage control signals

Comparing using Max to the modular, one participant focussed on the contrasting kinds of attention that the two environments promote, noting that when working with Max they would likely be thinking several steps ahead, whereas when patching with their modular instrument they are more likely to listen to the instrument before making the next connection (Participant 8).

> *When you're working with Max, you would probably be thinking six or seven steps ahead. When, when you were patching something you wouldn't, you wouldn't necessarily, you wouldn't necessarily be just making a connection in Max and then listening to that and then making the next connection.* Participant 8 interview 2020.

Another participant in reference to working with their modular using modules designed by various manufacturers noted a sense of interacting with other people's ideas that felt more immediate than their experiences of using Max.

> *I'm not so much trapped in my own head of sitting in front of a blank canvas and Max/MSP and just sitting there and building it. And, of course, a lot of Max/MSP is you using other people's objects to incorporate into ideas and things like that, so it's kind of very similar, but there's a real immediacy and geography to the modular version of it.* Participant 6 interview 2020.

Comparisons to Fixed Architecture Synthesisers

One participant reflected upon the differences between working with hardware-based fixed architecture synthesisers and their modular instrument, noting the possibilities for flexible routing and complexity (Participant 18).

> *There's a lot that I can do with the modular that I just would not feel is necessarily possible with fixed architecture [synthesisers]. I mean, yeah, there's a few things that I feel are kind of special for modular. Definitely flexible routing is, it does weird things to your brain I think, and I like that, because you can very easily get to a point where you're playing it and you don't really know what is going on.* Participant 18 interview 2020.

Eurorack compared to Buchla and Serge Instruments

One participant who works with a Eurorack based modular synthesiser, as well as a Serge system (Tcherepnin, 1979) and Buchla Music Easel (Music Easel | Buchla, n.d.) noted differences in these experiences due to the nature of the Buchla and Serge being designed by one person as a stand-alone instrument as opposed to a collection of interchangeable modules (Participant 21). They noted the fixed nature of these instruments, although modular causes a shift in their mindset as they are not considering changes to the instrument itself while utilising it.

> *I find the Easel, you know, Don Buchla who, the genius that created this, built it as an instrument, not as a set of modules, not as a system. And I think there's a really big difference in the mindset there because, you know, with modulars, which of course I have lots of. I have Eurorack. So, like probably many of us, I'm continually going, Oh, I can reconfigure that. What if this module comes first or this one goes out of the case and this one comes in the case.* Participant 21 interview 2020.

The relative stability of the Buchla Music Easel and Serge modular forms a consistency in the instruments that enables the participant to learn and understand the instrument, leading to confident interactions when performing (Participant 21).

> *[T[here's a lot of hard wiring under the hood, but there's a lot of patch programmability on the face plate with the Buchla Easel. It's more like playing a violin or a guitar… where you know, where the tuning pegs are, you know where the bridge is, you know where the strings are. They are not changing places. In fact, if they did change places, it wouldn't be a violin or a guitar. So it allows me to actually practise subtle, bold moves.* Participant 21 interview 2020.

Doubts about Modular

One participant expressed some doubts about their use of a modular synthesiser, wondering if they should have started with semi-modular instruments instead (Participant 18).

> *Being honest with myself, I kind of realised that maybe if I was starting from scratch again… I wouldn't have jumped straight into modular because… I wish that I had done what most people do, which is get a semi-modular. Like, most people get like a Mother 32* (Mother-32 | Moog, n.d.) *or like an 0-Coast* (Make Noise Co. | 0-COAST, n.d.) *… I really felt like getting a modular. I kind of jumped in the deep end in terms of trying to establish a music practice that [I] maybe didn't feel fully ready for.* Participant 18 interview 2020.

The same participant expressed a reluctance to engage with what they described as processes unique to sequencing within a modular synthesiser like logic gates or sequential switches, instead preferring to use their modular as a sound generator. They linked this to their desire to produce music that resembles existing genres (Participant 18). They jokingly referred to the implementation of sequencing processes within the modular instrument as ‘real modular’, and situated themselves as apart from this categorisation (Participant 18).

> *I feel like there are people that are this next level and sometimes I almost think of it, it's like real modular… not just the sound design… it's the sequencing as well and complex modulation. It'd be so cool to, like, you know, be one of those people that just… using logic and matrix mixers and… all this different stuff to control just modulation, like feedback networks.* Participant 18 interview 2020.

Concluding Practitioner Interview Analysis

In an effort to understand how modular synthesisers are used, how the experience impacts upon the process of music making, and why the experience is valued by musicians, I interviewed twenty-one musicians. While this approach could not hope to be an exhaustive survey of modular use, it did have the advantage of providing a depth of insight into a broad range of approaches. The selection of participants aimed to capture a diverse range of perspectives in terms of the age, gender and musical background of participants, and this diversity is reflected in the issues uncovered. The use of contextual inquiry techniques

provided richer insight into actual patching techniques and the structure of individual systems.

Many participants shared some of the aspects of my experience outlined in Chapter 4, but others came from contrasting perspectives.

The themes explored identified the role of the modular synthesiser in practice; how the participants came to use the modular synthesiser in their practice; descriptions of the processes and experiences of creating music with a modular synthesiser; participants' experiences of choosing modules, curating, configuring and developing their instruments; the importance of community; and finally, comparisons to the participants' experiences within and between other electronic music systems.

Despite its history, the modular synthesiser is in many ways a contemporary phenomenon existing at the nexus of electronic music, online communities, innovations in the commercial musical instrument market, a reaction to digital screens in everyday life, and a liberation in attitudes to music production and consumption. The challenge for the researcher is how to synthesise this diversity into a clear picture of this phenomenon. That is the goal of the following chapter.

Chapter 6. Discussion

The goal of this research is to understand how modular synthesisers are used, how the experience impacts upon the process of music making, and why the experience is valued by musicians. To answer these questions, I have examined and contributed to the histories of the modular synthesiser, engaged in practice as research, and empirically examined the experiences, attitudes and opinions of a diverse group of practitioners. Following the interpretive phenomenological method outlined in Chapter 2, Chapter 6 provides an account of the underlying essences, causes, and meanings driving the thematic descriptions identified in Chapters 4 and 5. This chapter thus presents the final process to be undertaken in a phenomenological research undertaking: Synthesis of Meanings and Essences.

Each of the four themes covered within this chapter offers an integration of key thematic descriptions, so that unified understandings of the structural meanings and causations can be offered. These themes are the instrumentalisation of the electronic music studio, modular synthesisers as compositional tools, the experience of discovery and co-creation, and finally, the modular as a contemporary phenomenon distinct from but building upon its historical precursors and context.

Instrumentalising the Studio

Modular synthesisers enable multiple components of a music studio, including mixing, effects, recording, and playback of recorded audio, to be situated alongside traditional synthesiser elements such as oscillators, filters, LFOs and envelopes in a coherent unified structure. Within the modular synthesiser, these elements interact in complex ways to form systems that enable any of the elements usually encountered in a broader music studio or software-based digital audio workstation to form a customised instrument that can be used for learning, performing, and composing.

The Modular Synthesiser is a Musical Instrument

The research participants used the term *instrument* to describe an intention for their modular synthesiser. Rather than describing a binary state – that is, whether the modular synthesiser is an instrument or not – they used the term to indicate the extent that their modular

synthesiser exhibited qualities they associate with their concept of an instrument. They identified stability and performability as the key qualities of an instrument.

Permanence and Limitation

The emergence of electronic music in the twentieth century complicated the concept of the *musical instrument* and necessitated a broadening of the term's previous meaning and a reappraisal of the elements forming its definition. In 1966, Pierre Schaeffer grappled with defining the musical instrument in the light of the music-making processes he had engaged with over the previous two decades. In describing the traditional acoustic instrument, Schaeffer (2017) noted an intersection of the attributes of the physical source (for which Schaeffer used the term *concrète*) and an abstraction brought about through repetition, performative expression, and musical structure. This abstraction obscures the physical source to varying degrees by partially decoupling the acoustic object from the variety of sounds it emits, but never entirely, as an awareness of the permanence of the source remains.

According to Schaeffer (2017), this permanence of an instrument's character comes about from the limitations the physicality of the instrument imposes upon its timbral possibilities and from the musical structures it can represent; for example, a tom drum cannot be used to play a 4-octave scale, and a violin cannot simultaneously bow non-adjacent strings. This permanence of the instrument through its physical, "concrete" form enables the performer to develop skills and approaches for that instrument through repetitive use and experimentation, safe in the knowledge that the instrument will not grow an extra string overnight or increase the size of its acoustic diaphragm.

In describing the shift that electronic instruments and recording processes had brought about in comparison to traditional acoustic instrument designs, Schaeffer (2017) noted that the electronic instrument forgoes the associative and complex relationships governing the potential timbre of an instrument, instead situating all variables as independent and discretely definable. The seemingly limitless potential of the electronic musical instrument, or of the electronic music studio, undermines the permanence of these instruments and equipment, effectively rendering them less like Schaeffer's definition of an instrument. This association of permanence, consistency, and limitations with the nature of a musical instrument aligns with the participants' descriptions of the modular synthesiser as more like an instrument that has stability, reliability, and focus in its form and function.

Similarly the desire to encounter difficulty, to have effort required in order to move forward in their practice sits alongside or within the concept of limitations. Participants' interests in not

utilising the quickest and easiest way but encountering problem solving processes in their use of their modular instruments echoes Joel Ryan's description of effort being an essential characteristic of musical expression (Ryan, 1992).

Performability

Schaeffer (2017) also differentiated between "synthetic musical instruments" and "studio instruments" such as turntables and recording devices, noting that instruments like the Ondes Martenot and the Theremin were configured to allow virtuosic use, whereas later ones were designed for radio broadcasting, their application by musicians being essentially a misuse or adaptation of their original purpose (p. 39). Few would now claim the turntable is not an instrument capable of virtuosic performance, given the rich history of turntablism since the 1970s. The acceptance of the turntable as an instrument is intrinsically linked to the virtuosic performances enacted with these devices (Collins, 2007). This situates the potential for nuanced and skilled performance as a key defining component to the conceptualisation of an instrument, but also emphasises the potential for a range of tools and objects not designed explicitly for musical performance to become an instrument through their use.

The participants associated the ability to develop skills and techniques to enable performance with their descriptions of their modular synthesisers as an instrument. They also noted the stability of their modular synthesiser as key to their building their skills and developing techniques, some describing an intention to limit the modification of their modular synthesiser's configuration as much as possible.

Physicality and the Instrument.

In describing their modular synthesisers as an instrument, the participants were mostly either contrasting their experiences with software-based approaches or aligning their modular synthesisers with fixed architecture hardware instruments such as a synthesiser keyboard or desktop sampler. Taking this into account, the characterisation of the modular as an instrument, or closer to an instrument, relates to the physicality of hardware-based modular synthesisers.

The physicality referred to here is not simply the description of an object occupying space; a laptop, desktop computer, or Arduino chip is also physical and might interact with our senses through touch, sight, and sound. Rather, it is the *affordance*, or degree to which the physical form defines its function through limitation and possibility (Gibson, 1983). Given the range of possible uses and the plethora of peripheral control devices, a computer used in a musical

context offers little in the way of specific affordances; instead, it leaves a question mark as to how the device will be deployed.

Mapping the Computer

The situating of computers as musical instruments surely occupies ground zero in the problematising of the concept of the instrument in a contemporary context. I was a witness to, and a participant in, the proliferation of the laptop in music performance in the late 1990s and early 2000s. The combination of computational power, flexibility, relative affordability, and portability makes their use attractive in both studio and live contexts. Most of the participants interviewed for this study had used a computer as their primary tool for music making and performance, and so many of their descriptions of using a modular synthesiser were made in comparison to their experiences with a computer.

Max Mathews, who is often referred to as the father of computer music (Grimes, 2011), identified early in the development of computers for music what is still a key issue for the computer as a musical instrument: “There are no theoretical limitations to the performance of the computer as a source of musical sounds, in contrast to the performance of ordinary instruments” (Mathews, 1963, p. 553). Mathews naturally situated this as a positive and powerful characteristic of the computer in the musical context, but this flexibility and absence of permanence also counteracts a computer exhibiting the characteristics of a musical instrument.

Much research and design has focussed upon how the computer as a musical instrument can be modified to allow a variety of interactions, as illustrated in the rich archives of the New Interfaces for Musical Expression (NIME) conferences and associated publications (Jensenius & Lyons, 2017). A recurring theme of many articles presented at the NIME conferences is that of *mapping*, which is essentially the correlation between the values derived from the interaction with the interface in question and the particular parameters and components of the sound-generating engine. The concern with mapping is necessary as the sound engines in question are largely enacted through computer-based software and have no intrinsic correlations to particular interfaces.

The issue of mapping interactions to the parameters of software indicates a key challenge for conceptualising the computer as a musical instrument, as there is little intrinsic permanence, as described by Schaeffer (2017). While a computer-based musician might carefully develop a sound engine and use a particular interface to control and perform that sound engine, the strategies and decisions guiding the linking of interfaces to sound engine parameters remain arbitrary. Those decisions may be driven by theoretical frameworks,

modelled upon acoustic instruments, or guided by principles of interaction design, but the computer itself provides no intrinsic limitations or guidance about the connections that might be made.

The mapping of interaction to a sound engine is also a process of imposing limitations upon that sound engine, thus defining how it might be used. A virtual instrument in a software environment might be controlled with hundreds of lanes of parameter-control data that can be carefully edited and composed to enable intricate structures to be arranged. Once the same sound engine is engaged in real time through performance, decisions must be made as to which parameters will be modified in real time. Even in situations where clusters of parameters are mapped through algorithms to specific interactions or combinations of gestures, there is still a reduction of discrete control, and particular combinations of parameters are no longer possible.

For a modular synthesiser, a process of mapping to provide interaction to the function and parameters of a patch is possible but not necessary, as the means of interacting through dials and sliders is presented and available in the physical form of the modules present. Through the process of patching and performing, the musician may identify key parameters and controls that they focus upon in a particular patch, but this does not correlate neatly to the concept of mapping, as the function of controls within the module in question existed before the intervention. There are a range of modules dedicated to extending the possibilities for interaction in a modular instrument, such as voltage offsets controlled by sliders, joysticks, large arcade-style buttons, theremin-inspired antennas, and even sensors that respond to changes in light levels. These can be connected within a patch to provide interaction control of the parameters the musician chooses, but they are not ubiquitous; some participants did not choose to include these kinds of modules in their systems.

The Physicality of the Modular Synthesiser

A consideration of the modular synthesiser’s physicality and affordances is necessarily multi-layered and somewhat contradictory. The modules making up the instrument's physical form are largely interchangeable, but this involves a physical process of removing and installing modules and the likely associated cost of buying and selling modules. Even the functionality of a modular synthesiser with a fixed configuration of modules is defined by how it is patched at a given moment, and these possibilities may seem endless. Yet abundant limitations are encountered due to the finite number and functionality of modules; only so many oscillators, VCAs, filters, and clock dividers are available for the current patch. In this sense, the

modular synthesiser exhibits a permanence of form and function far exceeding that of the multipurpose, software-defined computer.

For modular instruments developed by a single designer or company, such as the Serge Paperface or Buchla 200 series, this permanence increases due to the much-reduced range of possible configurations and compatible modules. This view is supported by the participants' descriptions, where they situated those seminal modular synthesisers as being "more like an instrument" in comparison to a contemporary Eurorack modular. It seems likely that the cultural significance and celebrated status of these older instruments also contributes towards them exhibiting greater affordances, recognisable timbres, and typified musical structures.

Given the configurability of a modular synthesiser, in particular the Eurorack format, the experience of encountering one offers little insight into its function or potential functionality to anyone aside from the musician(s) who use it. After a performance involving a modular synthesiser, it is common for a small group from the audience to gather around the instrument to point out particular modules or question the performer. While a range of intentions might be attributed to this phenomenon, including social agendas, I would interpret it as a desire to build a clearer understanding of the performance they have just witnessed. The ambiguity of a particular modular synthesiser's configuration and musical function undermines the instrument's permanence, as described by Schaeffer (2017). A piano, guitar, cello, or even a Roland TB-303 synthesiser communicates its possibilities and limitations through its physical form and associated semiotics far more clearly than a modular synthesiser.

The physicality of the modular synthesiser contributes significantly to its characterisation as an instrument, "or more like an instrument" in comparison to software-based approaches because of its significantly increased permanence. Due to the flexible configuration of a modular synthesiser, the affordances of the instrument to the musician who uses it or has specified its configuration are likely to be much greater than those offered to a more casual observer for whom the instrument's capabilities and limitations remain largely a mystery. Using the framework of comparison to software-based approaches, as suggested by the participants' interpretations, the contemporary modular synthesiser instrument may be understood as a compromise between the limitless possibilities of software and the limitations and permanence of a dedicated, fixed instrument.

Assimilating the Studio

Nearly all the modular synthesiser instruments customised by the participants incorporated elements not typically associated with fixed architecture synthesiser designs, including esoteric effects processors, multi-channel mixers, complex control voltage generators, sample recording, and audio playback. The following categorisations seek to broadly describe the conceptual origins of the various elements now incorporated into discrete modules available, particularly the Eurorack standard module. There is an overlap between these categories because the exercise is not designed to firmly situate a given module in a particular category, but rather to describe the variety of influencing paradigms upon the ever-expanding range of modules available.

Traditional (Fixed Architecture) Synthesiser Elements

Traditional (fixed architecture) synthesiser elements typically encompass oscillators, filters, VCAs, LFOs, envelope generators, simple small mixers, sample and hold circuits, slew circuits, and so on. These designs might be drawn directly from a particular synthesiser model, such as an oscillator from a Roland TB-303, a filter from a Korg MS-20, or an FM sound engine based upon a Yamaha *DX* synth. In other cases, the module may be a new design specifically conceived as a discrete module, such as an Intellijel Rubicon oscillator (Rubicon2, n.d.). Modules might incorporate several of these elements, with some modules offering an entire synthesiser “voice”. Control voltage is implemented for key functions, enabling possibilities not encountered in a fixed architecture instrument.

Modular Synthesiser-Specific Elements

Modular synthesiser-specific elements are components that are specifically associated with modular synthesiser designs. They include sequencing elements, function generators, stochastic generators, clock generators, clock dividers, Boolean logic gates, wave shapers, and vactrol-based amplifiers. These modules might slightly expand upon historic designs such as the Make Noise MATHS (Rolando, 2009) in relation to the Serge Dual Universal Slope Generator (Tcherepnin, 1979), or they might be substantial innovations with completely new designs such as Mannequins’ Just Friends module (Just Friends, n.d.). In either case, the key concepts and processes associated with the modules are predominantly fixed within the modular synthesiser and control voltage paradigms.

Drawn from Software

Several contemporary modules draw on software-based processes or designs. These include the application of software-based effects in modules such as the Make Noise Erbe-Verb reverb, the implementation of “tracker-based” sequencing like the XOR Electronics NerdSEQ (NerdSEQ, n.d.), and even entire virtual patching environments such as the Orthogonal Devices ER-301 (Orthogonal Devices, n.d.). These devices often take advantage of the CV-based patching environment to enable interactions with these modules that extend their normal use beyond that of software-based environments. For example, the NerdSEQ allows external CV to separately manipulate individual sequencer tracks, enabling possibilities not previously available with other implementations of a tracker-style sequencing approach.

Drawn from the Broader Music Studio

A variety of modules now enable complex mixing-desk functionality or effects such as compressors, delays, and reverb. In some cases, these have been completely rethought for a modular context; for example, the Frap Tools *CGM* mixer series offers individual mixer components such as channels, groups, and master outputs that can be combined to form a customised, CV-controllable mixer.

Drawn from Esoteric and Historic Instruments

Other modules draw their functionality or inspiration from specific electronic instrument designs or processes canonised in the recorded histories of electronic music. For example, Make Noise has produced modules such as the tELEHARMONIC (Make Noise Co. | tELHARMONIC, n.d.) and Phonogene (Make Noise Co. | Phonogene, n.d.), which as indicated by their names, are influenced by those unique early electronic instruments. The Mannequins W/ (W/, n.d.) module is another example that provides a simple digital version of a reel-to-reel tape recorder through the module’s more straightforward functionality. The Doepfer A-198, A-113, and A-104 (A-198, n.d.; A-113, n.d.; A-104, n.d.) are recreations of components from Oskar Sala’s Mixtur Trautonium; when combined with other Doepfer modules they enable the emulation of the functionality and timbre of the Mixtur Trautonium.

All the Possibilities

While the above categorisations are not exhaustive, I would find it too difficult to identify aspects of electronic music production or music studio technologies and techniques that have not been made available to some extent in the contemporary Eurorack standard. This broad sourcing extends the possibilities for a modular synthesiser well outside the

functionalities traditionally associated with the concept of a synthesiser defined by fixed architecture synthesiser designs.

Concluding Instrumentalising the Studio

This section has identified the broad range of phenomena that indicate how the contemporary use of a modular synthesiser is a means to shift the broader possibilities of electronic music production into the form of an instrument. The research participants explicitly indicated their intentions to experience something closer to their understanding of what a musical instrument is. They also identified characteristics such as risks, limitations, and permanence, along with the need to learn and practise with their modular synthesiser. These are the key components of the broader conceptualisations of what makes an instrument an instrument.

The capabilities encompassed by the participants' instruments replicate those of the broader music studio, namely, digital effects, recording and playback of audio, complex mixing and routing of audio, and sequencing of musical events. The participants acknowledged that these possibilities enabled them to shift the approaches and techniques they would otherwise undertake through hardware or software into their modular instrument. However, this transfer into the modular synthesiser paradigm also radically transforms how these broader electronic music processes are enacted and experienced.

Modular Synthesisers as Compositional Tools

A key component of the integration of the broader music studio into the modular synthesiser relates to processes, tools, and systems that enable musical events to be specified, recorded, and generated through sequencers and complex systems. These compositional components extend the role of the modular synthesiser beyond that of a sound-generating engine or of a traditional instrument that relies upon the moment-to-moment interaction of a performer, instead becoming a compositional tool that generates musical structure at a range of scales.

When we say "Composition"

Like the concept of instrument, the emergence of electronic music technologies in the twentieth century has complicated understandings of what elements and processes might be considered compositional. The ability to record sounds and to organise these recorded

sounds into layers and arrangements allows the act of composition to be a direct manipulation of sound rather than a process of notation and interpretation by musicians. The practice of improvisation in the twentieth century has also contributed to changes in our understanding of composition – agency is shifting to varying degrees from the composer to the musician(s) who enact the performance. One way around these complications is to start with the much broader concept of *music creation* and work back from there to see what, if any, differentiations might be identified in the roles and processes undertaken.

For music to be created, there must be sounds. Sounds have sources, and a range of activities and actors might be engaged in decision-making processes that determine when the sound sources are engaged, and to varying degrees how they sound. It seems reasonable to correlate the concept of composition with these decision-making processes. To enable a discussion that can remain generalised across a broad range of processes and musical forms, this conceptualisation is deliberately simplified to encompass all modes of music creation. Compositional decisions are made whether that creation is by a single improvising performer, orchestral music performed by software or live orchestra, a live techno act, a free improvisation ensemble, a piece entirely generated by an algorithmic system, or a rock band performing their greatest hits. These processes require humans working with systems and tools. Their decisions could include pitch or rhythm, the blending of sound sources, or changes across a range of time scales from the micro to the macro (Roads, 2004).

Fixed Architecture Synthesisers and Composition

The normalised conception of a synthesiser as a keyboard-based instrument situated the synthesiser as a possible element of sound similar to other instruments such as a piano or guitar (Dalgleish, 2016). Typically, a fixed architecture synthesiser will contain elements that can extend the instrument's responses beyond that of the moment-to-moment interactions of a performer. For example, a low frequency oscillator (LFO) might be applied to modify the instrument's amplitude to create slow pulsations or gradual changes in the filter cut-off frequency. In addition to these elements embedded within the sound engine, other specialised components such as arpeggiators or simplified step sequencers might also enable the automated repetition of pitch and amplitude information to the synthesiser's sound engine. In some designs, these elements form a key component of the instrument's identity, examples being the Roland TB-303's (Synth Legends, 2020) idiosyncratic sequencer, the Roland Juno 60's (Roland Juno-60, 2022) arpeggiator, and the parameter locking sequencers of Elektron instruments such as the Analog Four, Analog Rytm, and

Octatrack (Analog Four MKII - Synth | Elektron, n.d.; Analog Rytm MKII | Elektron, n.d.; Octatrack MKII - Sampler | Elektron, n.d.).

The introduction of the MIDI protocol to synthesiser designs in the early 1980s expanded the possibilities for fixed architecture synthesisers in compositional processes through the use of dedicated external sequencing instruments and software. This enabled a further decoupling of the instruments from real-time performance and interaction. However, these new possibilities for polyphonic sequencing and control of a synthesiser also situated the instruments as passive sound engines rather than as devices actively engaged in the structuring of musical form through their function.

Attributes of Modular Synthesiser Composition

The participants demonstrated and described a range of approaches where their modular synthesisers incorporated functionalities designed to determine when sounds would be emitted and to indicate relational variations in pitch or other variables of the character of the sounds. In many cases these functionalities significantly extend the possibilities for self-automated control of the synthesiser beyond those encountered in fixed architecture synthesisers.

The compositional processes described or demonstrated by the participants using their modular synthesiser typically involve an interconnection of multiple modules to generate gates and CV; these in turn control components such as VCAs or oscillators, which are more closely associated with the generation of sound. These systems of interconnected modules exhibit particular characteristics when compared to other hardware-based or software-based compositional approaches. In some cases, these characteristics are shared with patching-based software such as Max (Cycling ’74, n.d.), Pure Data (Pd Community Site, n.d.), and Reaktor (Komplete, n.d.). Given the flexible and idiosyncratic usage of patching software, the comparisons described below focus on the more commonly utilised DAW production and composition software titles. Later in this chapter I will examine the physicality of patching a modular synthesiser along with the contrasting experiences of patching in software and patching in a modular synthesiser.

Structure Generation and Manipulation

The participants demonstrated and described processes where they used their modular synthesiser to generate sections of musical structure consisting of multi-layered patterns of CV that were applied to pitch, duration, timing, and timbre. These sections could then be reorganised, phase-shifted against each other, distorted, and adjusted in real time. This

process of constructing musical structure at the meso and macro scales is a significant shift from typical sequencing approaches where musical phrases are pre-composed note by note, and then arranged or selected in a linear or dynamic fashion. This approach situates the role of the musician as overseeing and manipulating sections of musical structure as a real-time process, which is a shift not only from traditional note-by-note compositional approaches, but also from normalised electronic music processes where phrases are pre-composed and then arranged as a real-time process.

Improvisation

The generation of musical structure in real time enables the act of composing to be an improvised process that is incorporated into the instrument itself and can be practised and performed.

No Timeline

The mapping of musical events to a linear, typically horizontal, timeline to communicate and edit musical structure is almost ubiquitous in music making. Key elements inherited from the traditional Western music notation paradigm such as the left-to-right representation of time and vertical mapping of pitch are normalised across software-based DAWs and many hardware-based sequencers. In the case of most DAWs this timeline is presented as the default mode of music making, immediately situating musical events such as MIDI or recorded audio events upon the timeline. This representation and organisation of sound arguably foregrounds the scale of a whole composition or finished track as the primary goal, shifting the focus away from the immediate moment-to-moment experience and interaction with sound.

A notable and significant exception to this approach is the cell-based, *session view* first introduced in the software Ableton Live, where individual sections of audio and MIDI can operate independently or in relation to each other, free of an overarching timeline (Ableton, n.d. a). As the inclusion of the word *live* in the software title indicates, session view is specifically designed to enable improvised and responsive approaches to composition (Ableton, n.d. a).

The modular synthesiser also offers a reprieve from the conceptualisation of music composition as working upon and towards a linear and defined piece, where decisions are constantly invited and documented as parameter automation in relation to all possible scales of time, thus allowing these decisions to be revisited then modified or deleted. A modular synthesiser may include a range of modules that operate upon a timeline, such as an 8-step

sequencer, but these modules are operating within a broader interconnected system. Within the system, other timelines may also be operating in or out of sync, or working to an entirely different time base. Other components might intervene to reset, change the direction of a sequencer, or to modify the timing that triggers the sequencer. A modular synthesiser can still be used to enact carefully constructed musical structures over any timescale through recording or performance, or in some cases external sequencing, but the experience of composition with the instrument itself is firmly situated in real-time, moment-to-moment, decision making.

No Grid

Another significant contrast between composing on modular synthesisers and software-based or hardware-based composition is the quantisation of time. Alongside the aforementioned timeline, a DAW or sequencer will require an overall timing to be defined, usually as a measure of beats per minute (BPM). This master timing can then be divided or multiplied to enable musical events to be quantised in relation to this measure. The BPM might be changed at defined points in the timeline or as a real-time intervention into the sequencer. Some musical events might not be quantised, but there can only be one overarching BPM in operation at any given moment.

In contrast, a modular synthesiser has no inherent BPM and no inherent requirement for one to be defined. Multiple timing sources can contribute to the components of a composition interacting simultaneously or operating independently, and each individual module will work to their own internal timing unless a common time source is defined through patching. Various modules allow for a particular BPM and timing division to be enacted through clocked gates or trigger signals. For this signal to take effect upon other modules in the patch, the appropriate connections must be deliberately applied. The significance of this contrast is not because musical events in the modular synthesiser can occur outside of a quantised grid – this is true also of most sequencers – but rather that a quantisable grid does not exist unless the musician chooses to enact this possibility via the patching of the instrument.

Interconnectivity of Audio and Control Signals

In a software-based DAW or a hardware-based sequencer or sampler, there is differentiation between audio, recorded, or real-time signals and control information such as MIDI notes, MIDI CC messages, or internal automation data. While some modular synthesiser formats such as the Buchla deliberately differentiate between control and audio signals through the patching connections (Austin et al., 2011), formats such as Moog or Eurorack make no

distinction. In the case of the Eurorack standard, any output signal can be applied to any input, but in some instances the receiving input might not be capable of processing high-frequency signals, effectively filtering or slewing the input.

One outcome of this flexible approach to signals is that some modules can operate across broad timescales to undertake different roles depending upon their configuration and patched connections. A simple example of this is an oscillator tuned very low to produce slow variations in control voltage so as to perform the same role as a dedicated LFO. Some modules are explicitly designed for both audio frequency and lower-rate control frequency usage. An excellent example of this dual functionality is Mannequins' Just Friends module (Just Friends, n.d.), which offers either a series of envelope generators or an additive synthesis oscillator using the same analog circuitry.

In other cases, the timescale functionality of a module can be modified through patching to other modules while the internal functionality of the module remains the same. One example is a sequential switch, which is usually used to reroute audio or control signals with gate or trigger sources, being triggered by an audio frequency oscillator to form complex waveforms through audio frequency switching between multiple waveforms. Similar approaches can be undertaken with function generators (e.g., the Make Noise MATHS or Toppobrillo Sport Modulator) used as rudimentary oscillators at audio frequencies. This possibility is often encountered in modules that use analog circuits, as digital modules are often limited in their frequency range by the analog-to-digital (ADC) and digital-to-analog (DAC) converters, or the speed of the DSP microprocessor.

This flexibility encourages lateral thinking, as components of the modular synthesiser can be understood in the dual contexts of audio frequency generation and manipulation and musical event generation or manipulation. I suggest that this dual usage can also lead to a more comprehensive understanding of a module's fundamental functions by experiencing its use in these two distinct contexts.

Modular Synthesisers as Systems

The term *system* describes an object containing a number of interacting elements. The object might also interact with its external environment, but these interactions are of a "different nature or of a lesser intensity" (Bertuglia & Vaio, 2005, p. 3). A modular synthesiser fits this description well, and the word *system* helpfully brings attention to the interactions taking place within the instrument. The research participants described a range of patches, each a system with varying levels of complexity and degrees of agency assigned to themselves as performer and to the instrument. A key impact of the incorporation of the

broader contemporary music studio into modular synthesisers is that these elements are then situated in a system that is more defined and “intense” than the interconnection available in the external environment of the music studio.

The music studio, in both its physical and software manifestations, is no stranger to networking. Audio signals flow in complex networks through mixing desks, patch bays, DAWs, and plugins. In some applications these audio signals are extended beyond sound to be situated as control signals in compressor side chains, vocoder modulator signals and more recently, software-based analysis such as Ableton Live’s audio-to-MIDI conversion (Ableton, n.d. b). Similarly, other networks such as MIDI, DAW-based automation, or inter-software protocols such as ReWire (ReWire – Technical Information, n.d.) are also commonly encountered through music making and recording.

The networking enabled within a modular synthesiser significantly differs from these examples because it offers a homogeneous standard where all information is rendered interchangeable and non-hierarchical through voltage control. The process of integrating approaches and concepts from the broader music studio into the form of a module necessitates addressing the networked system of the modular synthesiser, often resulting in a range of connectivity possibilities not typically encountered. For example, a small analog mixer module may allow external voltage control of its individual channels, or an envelope generator may produce a gate signal to indicate when it has finished its cycle. These extensions of the possibilities for interconnectivity and related behaviours between modules and functions lead to the formation of complex systems with modular synthesisers.

Feedback, Chaos, and Complexity

The interviewed participants used the term *complexity* to describe experiences where the interconnections forming the system they had constructed in their modular synthesiser became difficult to keep track of, which led to them feeling confused or uncertain about the exact effect of individual components or interventions into the system. The process of forming this complexity in a patch occurs gradually because connections are made one at a time through patching so that systems can be formed that are not necessarily preconceived.

Complexity science or complexity theory draws upon observations and descriptions generated through attempts in the fields of mathematics and the sciences to model, understand, and predict phenomena encountered in the cosmos. These concepts are now applied in a broadening range of disciplines, from business and organisational studies (Kuhn, 2009) through to health (Rickles et al., 2007) and social work (Ewijk, 2017). Given the influence of analog computers, which were designed to model complex systems, upon the

initial development of modular synthesisers, there is a sort of ironic suitability in engaging complexity thinking in relation to modular synthesisers.

The term *complexity* is used to describe the behaviour of *complex systems* that consist of large numbers of smaller components that interconnect and interact in a non-linear fashion within a broader system (Rickles et al., 2007). The non-linearity of the interconnection means that a given system cannot be understood, modelled, or predicted based upon an understanding of its subcomponents in isolation because their behaviours are dependent upon their interconnection with other components within the system. As a result of these layered co-dependent relationships, complex systems produce behaviours that are difficult to predict and are highly sensitive to changes to any inputs or initial conditions.

Intersecting and sometimes encompassed within descriptions of complexity, *chaotic systems* can be composed of just a few components and no indeterministic elements and yet still exhibit seemingly random, dynamic behaviour due to the iterative use of recursive processes where the output of the system is fed back to an input (Smith & Smith, 2007). Components of a complex system might themselves operate chaotically, bringing further complexity to the broader system. Recursion or feedback in the generation of signals for CV or audio is possible using a modular synthesiser due to the flexible routing available, and some modules make use of feedback in their circuit design to produce chaotic signals (Fritz, n.d.).

A key characteristic of both chaotic and complex systems is that they are deterministic in that they adhere to sets of rules that could, in theory, be described, modelled, and replicated (Bertuglia & Vaio, 2005). There are no values involved that are random or indeterminate; instead, the uncertain and unpredictable dynamic behaviour occurs because the system is too complicated and detailed to be accurately predicted beyond a certain number of iterations.

The association of uncertainty and unpredictability in relation to complex systems correlates well to the participants' experiences of interacting with their modular synthesisers without clear ideas of the outcome, and their purposeful development of patches that become more complex than they were able to fully keep track of. The use of a modular system as a complex system for composition situates a level of agency in the instrument (system) and shifts the role of the performer to that of a collaborator with the system.

Both chaotic and complex systems are dependent upon their “initial condition” and highly sensitive to changes to any inputs from the external environment. This corresponds to the

participants' descriptions of small changes or interventions having a significant impact upon the outputs of their modular synthesisers.

Abstraction

A follow-on effect of the use of complex systems for composition is an abstraction of the musician's actions and decisions in relation to the impacts and resulting outcomes. Interactions and changes to initial conditions of a system result in unpredictable and dynamic changes to its behaviour. Some participants noted this as a positive impact, as their intention was not to specify musical events in terms of timing, pitch, or timbre, but instead to design and modify systems that would undertake those decisions to varying degrees.

This experience of abstraction can be distinguished from stochastic approaches where randomised values are generated. This is because a complex system is not necessarily random. This is significant because a complex system may not initially operate in a predictable fashion, but it can be learnt so that particular musical structures and timbres can be returned to or deliberately mutated in specific dimensions as delineated by the system and by the performer's interventions.

System as Score

The use of modular synthesisers to produce musical structure situates the system formed by the patching of the instrument as a key component of the resulting composition. The participants demonstrated patches and approaches, and they described interpretations that situate the system as a sort of musical score that would be repeatedly performed or recorded. These performances or recordings were viewed as documentation of particular instances of a composition.

The use of the electronic instrument as a score echoes the approaches undertaken by Gordon Mumma and David Tudor, both of whom designed and built their own electronic instruments and circuits, situating this process as a form of composition (Nakai, 2016; Nyman & Eno, 1999). This view of electronic music systems as forms of composition in themselves can be understood as a type of algorithmic composition where processes and rules are used to form musical structures. In the case of the modular synthesiser, the algorithmic approaches can be linked to qualities inherited from analog computing and instructional compositions, such as works composed by John Cage, where performed outcomes are dependent upon processes of indeterminacy and degrees of agency located with the performers or the environment.

The role of indeterminism reported by the participants and the large range of modules dedicated to embedding indeterministic processes in a modular synthesiser emphasise the score-like role of the patched modular synthesiser. The use of indeterministic processes increases the possibilities for variation within the rules defined by the system, encouraging each performance of the patch to be a unique version, and for the musician to experience a sense of discovery or be challenged to improvise with or against the system.

Ready-made electronic music composition tools such as a step-based sequencer in a fixed architecture synthesiser could, at a stretch, be viewed as algorithmic systems in that the processes and rules-based decisions are undertaken by the device. In these cases, the processes and rules are embedded in the architecture of the machine itself rather than opened out for the musician to define and modify; the musician is predominantly situated as a decision maker, determining when and what musical events are to occur.

In the case of composing music with a modular synthesiser, the musician is largely in control of the processes and rules that form the system. However, individual module designs bring subprocesses that determine to varying degrees what options are open for the musician to explore. The systems formed with modular synthesisers are dependent upon the modules available in the instrument and the connections made between these modules. The participants said they repeated iterations of particular systems to extend each system’s capabilities or to give it new qualities by refining it through changes to the patch and also by replacing particular modules. This approach led to the instrument being specifically configured in relation to a particular system or composition, bringing further definition to the instrument's limitations and capabilities.

This phenomenon further underlines the modular synthesiser's role as a compositional instrument concerned with the formation of music structure by drawing in the compositional possibilities of the broader music studio, but situating these factors is the form of an instrument that offers a level of permanence in its function. That the instrument itself changes through patching and the selection of modules does not undermine the permanence of the instrument, as this mutation is undertaken to define and refine the instrument's permanence so that the compositional intentions of the musician are more closely aligned with the nature of the instrument.

Physicality and the Patching Paradigm

In this discussion so far, the physical nature of the modular synthesiser has been considered as a component of its instrumentality. The physical form of the instrument, and in particular the physical patching paradigm, also impacts significantly on experiences of composing and

working with systems. The participants linked the physicality of their instrument to a range of phenomena, including performance, understanding their instrument, and forming habits in their use of the instrument.

Physical patching leads can be seen to add to the experience of complexity. As more connections are made, the patch leads obscure the module panels and make the connections between each module harder to discern. However, this physicality also brings a multisensory experience to the patch: modules occupy physical space, and the connections between them are tangible and traceable through touch and sight.

Cognitive Offloading

The ability to see and check what connections have been made in the system can be understood as a form of cognitive offloading, where physical action, or alteration to the physical environment, is used to assist in complex cognitive processes (Risko & Gilbert, 2016). The complexity reported by the participants, where the configuration of a system becomes too complex “to hold in their head”, may be offset to some degree by the physical nature of the patching. Another interpretation might be that the cognitive offloading offered by the instrument encourages and enables the musician to add further complexity to the system as they are able to check connections and maintain a multisensory awareness of the patch.

Embodied Cognition

The concept of embodied cognition recognises cognitive processes as arising from, and interconnected with, the physical world through movements and perceptions (Thelen et al., 2001). As we move, our perceptions necessarily change; this then feeds into our cognitive process, assisting us to understand and interact with the world. Embodied cognition situates these processes as a complex, networked whole. A musician working with a modular synthesiser is physically moving their body and shifting their point of view to better distinguish the connections made in the system or reach different components. In comparison to using a computer to construct a system, with a modular synthesiser there are unique, physical locations for components as opposed to the computer’s generic but flexible screen environment, where all components exist and their representational locations are amenable to change. If we accept that cognition is embodied, then it follows that a modular synthesiser will engage this aspect of cognition in ways that a computer cannot. It is beyond the scope of this research to make any judgement upon the impact of this idea, but it is reasonable to assume that it may play a role in the choice to use a modular synthesiser because of its physicality.

Leaving the Laptop

A desire to reduce their reliance upon computer-based tools for composition and performance was evident in the responses of many participants. In the broader sphere of electronic music production there is much interest in, and occasional critique of, the desire to create music outside of a computer, which is often referred to as “going DAWless” (Lines, 2019; QwelmQwolm, 2021). Many criticisms of the DAWless approach focus upon the ability of a computer to undertake the same processes and produce similar outcomes at less expense while also enabling the saving and recalling of systems and instrument settings.

Some participants indicated that they already use a computer all day for work and wanted to move out of that mode when creating music. Some also identified the blank canvas offered by software as a challenge, particularly the visual programming languages such as Max/MSP, and that the lack of limitations or directions offered by the flexible software environment provide little creative impetus. This description fits well with my own interpretation of the modular synthesiser enabling a greater level of permanence and limitation in comparison to software, and this aspect being valued by modular synthesiser musicians. Similarly, the participants' views that their modular synthesiser improves their own and their audiences’ experiences of live performance in comparison to a laptop supports the idea of the modular synthesiser being more closely aligned to the concept of an instrument than a computer.

Embedded Computing

The advent of small, accessible, and affordable digital processing components has contributed significantly to the increase in module designs available in the Eurorack format. These components enable much of the functionality of a module to be undertaken through programmable DSP chips rather than analog circuits. This significantly speeds development processes and draws upon skill sets outside the electrical engineering field. This same phenomenon also enables a range of DSP-specific functionalities that were previously associated with computer-based music to be embedded within a module. Examples include granular synthesis, granular audio processing, digital reverbs, digital delays, audio sampling and playback complex FM synthesis models, additive synthesis models, and physical modelling synthesis. Some participants demonstrated their use of these approaches in their modular synthesisers, noting that these capabilities enabled them to shift their practice further out from the computer and into their modular instrument while retaining or extending specific compositional approaches that were previously undertaken with a computer.

Solving Performance

For many interviewees the shift from a computer-based practice to a modular synthesiser was also linked to a desire to perform live more authentically, so that the process of performing more closely resembles the processes of composing and constructing music in the studio. Timeline-based processes, so prevalent in a DAW setting, are generally not suited to live performance and may lead to performances that operate within a reduced set of predefined parameters as the timeline plays. Rather than creating something new in front of an audience and risking failure, tweaking aspects of timbre or restructuring and collaging pre-composed blocks of sound events is often the most that might be expected.

This situation can result in a dilemma for computer-based musicians, in that the skills, knowledge, ideas and techniques that enable them to create music may not be engaged through live performance. Much thought is given to determining how something that is already constructed can be performed, often resulting in particular elements being controlled manually.

As mentioned previously, the Ableton Live session view (Ableton, n.d. a) approach is specifically designed to alleviate this dilemma by enabling the process of composing musical structure to be more flexible and non-linear. Another approach is that of Propellerhead's Reason (Reason | Reason Studios, n.d.), which is modelled upon a hardware-based studio with rack-mounted equipment and a simulation of physical patch leads. While Reason does include a timeline-based sequencer, other sequencers are embedded within devices or available in addition to the main sequencer, thus encouraging musicians to create and modify musical structure in the moment. The use of Cycling '74's Max (Cycling '74, n.d.) or the open source Pure Data (Pd Community Site, n.d.) can also be seen as a solution to the disconnect between compositional processes and live performance, as the musician can create a customised system or instrument to compose and perform with.

The modular synthesisers' ability to create and manipulate musical structure as an improvised process resolved this dilemma for some of the participants interviewed. Their modular synthesiser enables them to bring their compositional processes out of the studio into a live performance with minimal alteration. The inability of a modular synthesiser to save and recall its state brings a sort of performative risk to its use in a studio context, as a patch must be performed and recorded or else it will be lost when the instrument is repatched. This ubiquity of performativity across contexts is a key aspect of the modular synthesiser functioning as an instrument and its solving of the performance problem for electronic music.

Concluding Modular Synthesisers as Compositional Tools

The nature of a modular synthesiser as an interconnected system for music composition generates a range of phenomena, including complexity, abstraction, increased possibilities for improvisation, and the embedding of a musical score in the instrument itself. In particular, the implications for composition of musical structure from the micro to the macro, and the level of agency ascribed to the instrument represent a key component of the experience of using a modular synthesiser. The next topic examines the participants' experiences of discovery and co-creation.

Discovery and Co-Creation

A key phenomenon observed in this research is the intention to experience music composition as a process where unexpected but constructive elements emerge through processes that use the modular synthesiser instrument. The participants closely linked this experience to conceptions of co-creation, situating themselves as working collaboratively with the instrument. Experiences of discovery are not unique to modular synthesisers, nor even electronic music. Improvising or “noodling” on a piano might enable “discoveries” of melodic or rhythmic structures that were not pre-planned by the composer. In that sense, discovery might be understood as a key component of almost any compositional process. Electronic music instruments seem particularly suited for processes of discovery. Because many instruments, sequencing devices, and software operate according to their own idiosyncratic logic, a musician might not fully understand the ramifications of all the decisions they make in relation to the devices’ functions and so may discover new ideas through processes of experimentation. An arpeggiator is a good example of a commonly used function in electronic music making; it forms patterns and structures based upon a combination of rules and real-time input that can enable new possibilities to emerge.

Some electronic instruments are notorious for being so idiosyncratic or obtuse in their internal logic, function, or interaction that this aspect of their use is synonymous with their identity. An example is the Roland TB-303 synthesiser (Synth Legends, 2020), which, according to legend, was a commercial failure that went on to become a sought-after collectors’ item because of its unique sound. The sound of a TB-303 is not due solely to the architecture of its sound-making elements but also to its unique approach to sequencing, including accents and note-slide function. The sequencer of a TB-303 is notoriously difficult to program, at least in the conventional sense of deliberately defining a pattern of notes,

accents, and slides. The Chicago band Phuture, which is credited with the first use of a TB-303 to produce the acid house sound with their recording “Acid Trax” in 1985 (Saxelby, 2014). found the sequencer difficult to understand, and the resulting acid house genre reflects this, with almost entirely random collections of notes forming repetitive patterns. In the case of the TB-303, the complexity and unintuitive sequencer and programming interface results in experiences of discovery of timbre and musical structure.

The use of the term *discovery* by some participants describes elements within their compositional process that extend beyond planned or intentional actions and decisions. They were open to these possibilities and deliberately used processes and tactics designed to support the possibility of experiences of discovery to occur. That these elements are described as discoveries infers a desirability; other elements of structure or timbre may emerge only to be rejected or avoided by the composer. For these possibilities to occur the composer must give a level of agency to the instrument itself. This may be conceptualised as a balance between controlled, planned, or deliberate actions the and relinquishment of control through experimentation, generative systems, or indeterminacy. I have classified the participants’ experiences of discovery using two broad differentiations: *process-based discovery* and *designed discovery spaces*.

Process-Based Discovery

In process-based discovery experiences, the participants encountered possibilities through the process of patching their instruments and experimenting with connections and through the relationships between modules. They reported experiences where their instruments “suggested” possibilities through apparent connections or functionalities of modules. These experiences, which require the composer to be open to experimentation and to undertake open-ended processes with the intention of developing possibilities that are not foreseen or pre-planned, are discussed in more depth below under the subheading “Physicality and the Patching Paradigm”.

Designed Discovery Spaces

Some participants also designed patches and instruments to elicit unpredictable elements such as sound structures or timbre variations. In these cases, the scope of the variation was delineated to specific parameters within the patch and the variations could be invoked continuously or discretely. These processes are covered in more depth under the subheading “Systems Design and Discovery”.

Creativity and Discovery

The concept of discovery can be situated in relation to a creative process in two distinct ways. A creative process might be undertaken with an intent to *discover* something: an original idea, a component of a musical structure, or a new way to make toast (Runco, 2014). A creative process can also embrace discovery through experimentation and other tactics that produce unforeseen possibilities.

The participants did not explicitly state that they conceived their use of a modular synthesiser as a creative process, but given their intention was to make music or sound, often in an exploratory fashion, it seems reasonable to situate their activities in relation to their experiences of discovery as a form of creative process. Research on creativity is diverse in focus, method, and even definition, ranging from attempts to understand adaptation and problem solving encountered in the everyday through to the endeavours and processes of artists, and also innovation and invention in science and business settings (Runco, 2014).

There are incompatibilities between my own sociological phenomenology-based methodology and the methodologies most associated with research into creativity. Research into creativity can be broadly categorised into two approaches: the “puzzle-problem” approach, which seeks to understand creative processes through experimental, cognitive psychology or neurological testing; and the “great-minds” approach that draws upon biographical information of recognised artists, scientists, and innovators (Sternberg & Davidson, 1995). In either approach, the designation of what is considered creative, or successfully creative, is defined externally to the subject's own reckoning. In the case of the puzzle-problem approach, the research model defines the successfully creative efforts as “correct” solutions or statistically unique responses, with either situated outside the subject’s own valuation or reckoning.

The great-minds approach makes use of hindsight and the cultural valuation attributed to acclaimed achievements of art, literature, music, or science. In this case, the subject’s own internal process of valuation and recognition of what constitutes something as being creatively successful is not necessarily accessed. My own research method solely privileges the participants' interpretations and descriptions of the processes, actions, and outcomes they perceive as being creatively successful.

Given the focus of my research is on understanding and examining the experiences of people who use a modular synthesiser as described through their own interpretations, a

comprehensive discussion of the entire field of creativity research is unnecessary. However, there are intersections with particular theories and findings from research into creativity that offer useful insights into the interpretations and processes shared by the participants, in particular the role of the modular synthesiser instrument in these processes.

The concept of discovery is related to creativity but often associated with achievements made in the fields of science or mathematics (Runco, 2014; Runco et al., 2011). Thomas Kuhn (1996) characterised all discoveries as having been preceded by an awareness of an anomaly, the discovery itself being a simultaneous emergence of observing phenomena and conceptualising an understanding or recognition of the phenomena. In my framing of creativity and discovery, discovery is something that is found or encountered, and creativity is the process that leads to the discovery followed by a recognition of its significance (Runco, 2014). The use of the term *discovery* by the participants differs in that there is no inference that a given possibility they encounter through a process of discovery pre-existed their encountering it. In this case, the understanding or recognition of the discovery is an aesthetic process in that the musician is listening, considering, and assessing their experience of the sounds and music to determine if the outcome is desired.

An Aesthetic Evaluation

Much research has been undertaken, particularly in the field of psychology, to describe and understand the processes that occur within an aesthetic experience. Of particular significance in relation to the experience of discovery as described by the participants are the cognitive processes that seek to understand and classify that experience in relation to other experiences. The familiarity of an experience impacts upon the likelihood of a positive evaluation of it (Leder et al., 2004), as might be expected when there is an intention to classify or integrate an experience. However, an entirely familiar experience may not invoke a process of aesthetic evaluation or be situated as an experience of discovery as described by the participants. Similarly, an experience that is entirely novel or too far removed from prior experience or available schemas may result in confusion (Silvia, 2009).

The participants' process-based discoveries when they patched their instruments enabled them to gradually incorporate new possibilities into their schema, a process called "cognitive mastery" (Leder et al., 2004). In turn, this allowed them to assess the new component or aspect of the patch and evaluate its desirability. In addition, their experiences of designed discovery spaces enabled them to carefully denote where and how new and unknown possibilities might occur in the instrument system and thus shepherd them into the fields of variation they would be interested in exploring. Experiencing both types of discovery enabled

the participants to control the levels of novelty and familiarity they felt aesthetically comfortable with.

Delving further into the emotional and cognitive processes associated with aesthetic reactions and evaluations, Paul J. Silvia (2009), offers a consideration of the emotions *surprise* and *interest*, which he categorises as “knowledge emotions” (p. 48). Knowledge emotions are associated with the process of comprehension and thinking about the aesthetic experience being considered. *Surprise* is the appraisal of “something as novel and unexpected” (p. 49). The participants' descriptions of discovery-orientated processes would indicate a desire to experience surprise.

Closely related to surprise, *interest* occurs when the experience is unfamiliar and complex, but still comprehensible. For the participants, interest was clearly a component of the discovery experience, but how they might have comprehended their experience would likely have differed from participant to participant. For some, their interest might have related to their ability to understand what was occurring and the specific effects encountered as a result. This may have enabled them to incorporate a particular technique or combination of module functions into their practice, and also to deploy it in other patches or extend it further through deliberate experimentation. In other cases where complexity was closely linked to the experience of discovery, the participant was intervening in a system that was too complex for them to fully comprehend the mechanisms that had resulted in the experience of discovery. In these cases, interest could still occur, but comprehension might have been connected to performing with and in relation to the encountered phenomena, rather than attempting to fully understand their operation.

Divergent Thinking

Divergent thinking is associated with creative processes and has been used to study and measure the cognitive processes associated with creativity (Mednick, 1962; Runco, 2014). Divergent thinking is usually understood as an internal cognitive process, but the participants' descriptions of working with complex systems or indeterminate elements suggest that a form of divergent thinking was invoked through their instruments. In other words, possibilities surfaced through the design of the system, which, after consideration, were accepted (discovered) or rejected by the musician.

Remote Associations

Sarnoff A. Mednick used divergent thinking for his Remote Associate Test (RAT), which sought to establish a basis for measuring creativity independently of a particular field or

medium (Mednick, 1962). In some tests, Mednick's participants were asked to produce multiple solutions or associations in response to a series of seemingly unrelated words. Mednick found that ideas produced later in the process were more likely to be "original" or creative responses, according to his criteria, than those produced earlier in the process (p. 223). Mednick's criteria for measuring creativity was an intersection of the solution's originality, as determined by the likelihood of a test population producing the solution, and its "usefulness", which is arbitrarily defined by the experimenter and described to the test participants (p. 221). The intentional invoking of experiences of discovery by the participants in my own research may be interpreted as processes that provide a shortcut to original ideas, using the design of their instrument system to encourage the usefulness of the new possibilities according to their own criteria.

Abstraction

The participants' use of the term *abstraction* was related to their experiences of interacting in complex systems where they had conceptual disconnects between their actions or interventions and the resulting outcomes. This use of the term does not sit neatly with the use of abstraction in relation to creativity research, where it describes a mental process of mapping or recognising patterns and structures to form conceptual models that define relationships between specific tangible elements of a process (Welling, 2007). However, the concept of abstraction in relation to creativity as proposed by Hans Welling does offer an insight into what the participants valued about this experience. They did not use abstraction to describe experiences of working with indeterminacy; rather, it was invoked in relation to complex systems where they had identified particular parameters that would elicit changes in the system that were surprising or hard to predict.

Working with those complex systems to then improvise and perform would have logically entailed a process of conceptually mapping the relationships between elements based upon the changes and effects they could observe in the system's behaviour. This conceptual mapping or abstraction does not imply an exact or comprehensive modelling of the individual relationships entailed within the system, as the complexity they encountered precludes this. Instead, it would have enabled other "cognitive operations such as symbolisation, classification, discrimination, generalisation and pattern recognition" (Welling, 2007, p. 171). In the context of music composition, these cognitive operations identified by Welling would likely enable a broader perspective where structural components can be considered and manipulated. This description of abstraction sits well with participants' descriptions and demonstrations of complex systems, where their agency in the system was focussed upon broader structural changes rather than on specific note, timbre, or timing delineation.

Problem Solving and Adaptability

The concept of problem solving was reported by the participants as a positive component of their experience of using a modular synthesiser. Processes of problem solving were also evident through my observations of the participants working with their instrument. Research into creativity often uses processes of problem solving as examples or tests of creativity, and it is accepted that creativity can form a component of problem solving (Runco, 2014). Problem solving was described by the participants when they sought to overcome something they perceived to be blocking them from proceeding with a process they were attempting. Their valuing of the problem-solving process was attributed to the intellectual and creative challenge it presented and to the potential for new possibilities to be encountered through the process.

The ability to be flexible and to adapt behaviour in response to the environment are intrinsically connected to creativity, as both are descriptors of creative acts and essential components of the creative process (Runco, 2014). Adaptation was evident when the participants found workarounds to problems they encountered or embraced sounds and structures generated through their instrument system. Given the limited physical nature of any given modular instrument, it is reasonable to infer that a level of adaptability is necessary when working with these instruments, as the components available may not always suit the musician's exact intentions. The inclusion of a variety of modules with eclectic functions in the configuration of some participants' instruments suggests their intentions to enable flexibility. Or it may indicate these participants had broader aesthetic intentions than those whose instruments were more tightly configured for a specific approach.

If flexibility and adaptability are components of the creative process, then the use of modular instruments may encourage the development of these traits. The participants reported that the modular synthesiser “changed how they think” and how they approach music making generally. Increases in flexibility and adaptability are likely components of such changes.

Tactics

The term *tactics* describes the deliberate approaches that assist in a creative process. The application of a tactic is metacognitive, as the intention is to consider and modify one's own cognitive processes (Runco, 2014). Tactics themselves consist of procedural knowledge and defined processes or sub-processes that might be designed in relation to specialised situations or to be broadly applicable. For example, in the context of this study a tactic might be applied to a sampling module where musical structure is constructed through

manipulation of the sample start position. This would be an example of a specialised tactic that would not lend itself to cases where a sampler module is not in use. Another tactic might relate to using audio rate signals to manipulate other components of the patch, perhaps using sample and hold or slew circuits to manage the impact of the ensuing feedback loop. In this case the tactic might be applied more broadly to a range of situations and configurations of modules.

The participants demonstrated and described the various tactics they use. Some might be described as purely cognitive processes, like choosing to explore a capability of a module they have not tried before. Other tactics might be components of a patch, for example, the use of randomised values generated within the patch and applied to specific parameters of the patch. In this case the procedure is embedded within and enacted by the instrument itself through its patching.

Flow State and Modular Synthesisers

The concept of *flow* was first articulated by Mihaly Csikszentmihalyi (2009), based on findings from a range of studies he and others had conducted since the 1960s seeking to understand activities, including those of artists, where the activity seems to be intrinsically motivated. His seminal work, *Creativity: Flow and the Psychology of Discovery and Invention,* was based on interviews with more than 90 individuals identified as being creative in their fields of endeavour in order to understand the subjective phenomenology of their creative processes (Csikszentmihalyi, 2009). Csikszentmihalyi describes the experience of flow as a state where the person is fully engaged in the activity, adjusting their actions based upon real-time feedback and working with challenges their skills can meet. The activity undertaken is enjoyed and valued as an experience and clear goals are identified, yet the activity is not just a means to an end; the resulting focus resists any distraction from the task at hand. The participants in my research identified that they experienced flow in working with a modular synthesiser, the term having been recently popularised in a range of contexts. Participants also described elements of these experiences that correlate well to Csikszentmihalyi's definition.

Immediate Feedback

A key component of the flow experience is for the person to know how they are going by receiving immediate feedback on their actions (Csikszentmihalyi, 2009). The real-time nature of working with a modular synthesiser enables this, and it was identified by participants as an important and valued aspect of their experience.

Balancing Challenge and Skills

Csikszentmihalyi (2009) describes the flow experience as having a delicate balance between the challenge presented by the activity and the skills and knowledge of the person undertaking it. If the activity is too difficult then this will result in frustration and anxiety, but if the activity does not offer enough challenge boredom will ensue. The participants in my study described their use of the modular synthesiser to both generate difficulty and solve problems. The ability for a musician using a modular synthesiser to be quite in control of the level of complexity of a patch allows this balance to be adjusted incrementally so that the complexity of the challenge is customised to suit them as they progress. This echoes Csikszentmihalyi's description of graduated challenges and increasing complexity in relation to a person's skills (Snyder & Lopez, 2005).

Resisting Distraction

When in the flow state, a person is attentive to the activity at hand, ignoring other concerns (Csikszentmihalyi, 2009). The participants identified the modular instrument as assisting them to remain focussed through its limitations when compared to a computer-based composing environment. It might also be supposed that the generalist nature of a computer, with its access to emails, social networks, and work tasks can allow a range of distractions to be foregrounded, and hence the specialised modular synthesiser offers a comparative reprieve from the networked world.

Modular Synthesisers Support the Flow Experience

As these correlations suggest, it is reasonable to describe modular synthesisers as being supportive of musicians finding and working in a state of flow due to the intrinsic qualities of the modular synthesiser as an instrument with limitations and varying complexity. Even so, it is capable of situating music composition outside the computer-based paradigm.

Co-Creation and Instrument Systems

The participants described recognising and giving over their agency to the instrument in relation to their processes of composition, and in some cases they explicitly linked this to their experience of discovery.

Co-Creation and the Modular Instrument

Before examining the role and impact of complex systems in relation to experiences of co-creation, it is useful to first consider what the inherent qualities of modular synthesisers might also contribute.

Limitations

The relative limitations imposed by a modular synthesiser in comparison to software situate the musician in constant but variable degrees of compromise. At one end of the scale lie the continual, unavoidable limitations on polyphony and the saving or recall of the instrument's state. Moving across the scale, the issues become more specifically related to the intentions of the musician, as it becomes apparent that the numbers of VCAs, filters, oscillators or other components are insufficient for undertaking the intended approach. As these issues are encountered, the musician must then problem solve, engage divergent thinking, and reshape their intentions to their instrument's capabilities.

This experience of the instrument seeming to push back against the musician, or at times enabling and encouraging workarounds, necessitates a transfer of apparent agency from the musician to the instrument and a collaborative shaping of purpose and process. This is the case with any instrument because limitations are key components of something being understood as an instrument per se. Something about the experience of using a modular synthesiser would seem to foreground this component of the experience, despite it being a very flexible and configurable instrument. It may be that the instrument invites open-ended exploration and experimentation to a greater degree than most hardware-based instruments and commonly used music making software. So, when limitations are encountered in a modular synthesiser, the musician is more cognisant of having encountered a limit rather than proceeding through the established workflows supported by more limited instruments. The ability to circumvent limitations so that they do not completely block a possibility may also contribute to why limitations are noticed and appreciated in a modular setting. In addition, the physical nature of the modular instrument may affect how its limitations are conceptualised and mapped by the musician.

Electronics Speak and Patch Programmability

Some participants mentioned the concept of *patch programmability*, a term introduced by Serge Tcherepnin to describe module designs that can perform a variety of functions depending upon the way they are patched (Scott, 2016). An early example is the Dual Negative Slew, which can be "programmed" to perform as a voltage-controlled pulse source,

an envelope follower, a sawtooth oscillator, or envelope generator. This flexibility is achieved by presenting lower-level electronic functions that do not presuppose a specific musical purpose. Tcherepnin described this as privileging the electronic circuitry itself through a desire to “free the electronics so that it could speak for itself rather than be enslaved to pre-conceived concepts of what musical sounds are like” (Biddulph et al., 2018).

The influence of patch programmability and Tcherepnin’s designs is evident in a range of contemporary modules, particularly in the Eurorack format. Modules such as the Make Noise *MATHS* and Toppobrillo’s Sport Modulator reimagine, repackage, and extend Tcherepnin’s designs. The concept of patch programmability can also be seen applied in the use of binary operations for the control of the Statues multiplexor module by Nonlinearcircuits (Statues, n.d.), where the processes and language of the circuitry or chip are privileged over any assumed musical use.

Tcherepnin’s concept highlights the influence of the electronic nature of the modular synthesiser instrument, inferring that its processes, interfaces, and functions exist in other contexts outside of music and that circuitry has its own character and affordances that can be brought to the foreground. These lower-level functions drawn from the circuitry itself contribute to the instrument's agency in creative processes, open new possibilities, and impede or redirect user’s intentions.

Embedded Instrument Design Ideologies

Each module included within a modular synthesiser brings processes that enable possibilities through combinations with other modules within the instrument. The processes and connections offered and how they are presented are both representations of, and outcomes from, the assumptions and preferences held by the module designer or design team. These design ideologies consist of predilections about how music can or should be made, the role of the modular instrument, and even what should be considered music.

A stark example of a difference in design ideology can be seen by comparing Serge Tcherepnin’s and Don Buchla’s approaches to control voltage. Buchla deliberately separated gates (or triggers), audio, and control voltages into distinct signal types and justified this as a means to reduce the complexity of the system and technical requirements of each of these signals (Austin et al., 2011; Buchla, 1966). Tcherepnin, who had in-depth experience of a Buchla instrument through his work with Morton Subotnick in New York, made a deliberate decision that all signals – audio, control, and timing – should be interchangeable to allow the musician greater scope for experimentation and to enable Tcherepnin’s own ideology of patch programmability (Scott, 2016).

In the case of those instruments, or of modular formats developed by a single designer or manufacturer such as the Buchla and Serge, there is a level of consistent intentionality across the design. When these systems are compared to a contemporary Eurorack instrument that might be formed from dozens of different modular manufacturers, there is a stark increase in the range of ideologies present within the instrument. The participants who were able to compare experiences between Eurorack and other formats noted this difference and also referred to how the designers' ideologies influenced their practices.

Designer ideology is also present in individual Eurorack module designs. Given the ambiguity regarding what modules present in an entirely customised instrument, designer assumptions are particularly noticeable in the inputs and outputs that are made available. A simple example of this is in the various envelope generator designs. Simple designs might only offer a trigger or gate input, assuming that the envelope will perform its standard function of parameter modulation without itself being modulated. Some designs allow each parameter – typically attack, decay, sustain, and release – to be controlled by another source external to the module. Other designs significantly extend the possibilities of the envelope's function by including trigger outputs that are activated when the envelope finishes its cycle, or a specific stage of its cycle. This enables an envelope to function as a complex LFO or as a trigger source and to interact with other modulation sources to form complex systems.

The ideologies embedded in the instrument bring particular possibilities to the foreground, and limit or prevent other approaches from being explored. Similar to and intersecting with experiences of limitations, an embedded ideology contributes to an instrument being experienced as a sort of collaborating co-creator. However, this can be a nuanced influence that can shift how a musician approaches and conceptualises music making.

Systems Design and Co-Creation

Joel Chadabe coined the term *interactive composition* to describe processes and performances in which a human improviser and a system share responsibility for compositional decisions in a real-time process (Chadabe, 1984). Chadabe (1997) cites the CEMS System, an instrument of his own design developed in collaboration with Moog, and the SALMAR Construction developed by Salvatore Martirano, as the earliest examples of interactive composing instruments (p. 291). Both were large instruments, configured via patch cords, and they can reasonably be characterised as idiosyncratic examples of modular synthesiser design. Much of Chadabe's later writing upon the subject explicitly identifies computers as the site of the systems in question; however, given the inclusion of those two

analog systems as the earliest examples of interactive composition, the term was not intended to exclusively refer to computer-based systems.

Chadabe's (1984) definition of interactive composition calls for a system to first be devised, and then composition to occur through real-time interaction with the system (p. 22). This focus upon real-time interaction distinguishes Chadabe's descriptions from much of the other histories of computer music and algorithmic composition that developed from non-real-time systems due to the limitations of digital computing in the 1960s and 1970s. Chadabe's focus upon real-time interaction necessitated the use of a synthesiser, a Synclavier 1, to produce the sound, even when he was able to access a portable computer for his pieces *Solo (*1978) and *Rhythms* (1980) (Chadabe, 1984, p. 24). Along with his concept of analog-based systems, Chadabe's inclusion of synthesisers as a distinct component of the compositional system suggests a lineage that is closer and more sympathetic to experiences of complex systems in modular synthesisers than broader histories and conceptions of computer music and algorithmic composition. Chadabe's focus on the relationship of system and performer provides a useful lens for exploring the phenomenon of co-creation reported by the participants.

Similar to the participants' experiences of surprise at discovering new possibilities through their interaction with the modular synthesiser as a system, Chadabe (1984) describes unforeseen changes and an unfolding of music through performance in interactive composition. He describes a balance being formed between the novel properties and the sufficient familiarity of the emerging music through the sharing of control between system and performer: "The seemingly contradictory qualities of newness and recognizability are brought together through shared control. The performer controls certain of the composition variables and the response algorithm controls others" (p. 25). Reflecting on my own experiences of composition and on the participants' descriptions of their practice, I suggest this balance is formed through a process of iterative modification of the instrument's system or patch. Expanding and contracting the degree that specific elements are governed by the system by the performer, or as a combination, delineates the "discovery space" identified at the beginning of this chapter.

Given the agency of the musician in defining the compositional system, these experiences of co-creation might be understood as entirely deliberate, with the resulting discovery space well defined and the collaborative relationship with the instrument decidedly one-sided. However, the act of intervening into a complex system through performance and improvisation can cause flow-on effects and chaotic behaviours to the extent that the discovery space becomes unstable, losing its defining boundaries or collapsing into a level

of complexity that causes the musician to no longer feel confident in their interventions and to lose their agency in the co-creative relationship. This can then result in the musician repatching the instrument partially or completely, a process of reasserting control by reducing the complexity of the system, and then gradually adding complexity back in.

The use of complex systems as a deliberate tactic designed to elicit experiences of discovery also relates to the authorship of the resulting material. An experience of discovery may occur in the process of auditioning a sample library and juxtaposing pre-recorded segments of sound together. In this case, the sense of authorship for the musician may be at least partly compromised. However, the use of a system to generate new material that is incorporated, modified, and performed upon does not seem to problematise the authorship of the musician in the same way, especially if they have designed the system themself.

Concluding Discovery and Co-Creation

The participants situated their use of modular synthesisers as a deliberate strategy to encourage unforeseen possibilities and divergent thinking. Their giving over of agency through deliberate experiences of discovery and their conceptualising of a co-creative relationship with the modular synthesiser instrument sit uncomfortably with common understandings of the role of music technology. Rather than seeking out an obedient technology capable of realising their intentions and reducing the labour involved, the participants sought to have their ideas and objectives challenged and contorted. Their agency was instead invested in designing and arbitrating the degree and nature of the possibilities presented through the configuration of the instrument and specific systems they designed.

The benefits of technology that are often assumed in music making, such as the ability to create any sound and to organise and realise multi-layered compositions, situate the musician as an empowered decision maker whose ability to realise their ideas is amplified by the use of technology. Instead, the participants described how they wanted to explore possibilities and have their own intentions shaped and changed through their use of the instrument. Their agency was invested in designing and arbitrating the possibilities presented through their configuration of the instrument.

The Contemporary Modular Synthesiser

This section discusses phenomena that are significant but disparate. The title emphasises a relationship between the contemporary resurgence of interest in modular synthesisers and their use. It is beyond the scope of this research project to explain why the resurgence has occurred, but many of these ideas described here could reasonably be understood to contribute to the motivation to use a modular synthesiser. Other components of this section might not be recognised and understood outside the context of the broader landscape of contemporary electronic music making tools available today, and some discussion points rely upon historical hindsight endemic to a contemporary point of view.

Legacies and Diversions from Historic Development of Modular Synthesisers

The contemporary resurgence in the use and commercial sales of modular synthesisers draws upon historic modular synthesiser designs from the 1960s and 1970s. Continuations and diversions from this history form significant aspects of the participants' experiences of using modular synthesisers.

Tape Music in Real Time

The primary design impetus for the earliest modular synthesisers was to shift tape studio practices into real-time processes, enabling performance and improvisation (White, 2022). As the large and extremely expensive instruments were simplified and commercialised to become keyboard-based, many of the possibilities for real-time manipulation of musical structure were lost. The participants emphasised aspects of their experiences and of their instruments' capabilities that relate to the capability of forming musical structure in real time. They also pointed out key differences between these processes and those that they associated with software- or hardware-based sequencers or editors. The contemporary resurgence in the use of modular synthesisers indicates a return to the more fluid and flexible real-time compositional processes endemic to modular synthesisers.

The use of the stand-alone approach to composition with a modular synthesiser described by many participants can be differentiated from most fixed architecture synthesisers, which are designed to either be physically played in real time using a keyboard or externally sequenced via MIDI. Some hardware-based electronic instruments do incorporate their own sequencers, often exhibiting unique characteristics, such as the Roland TB-303 (Synth Legends, 2020) with its slide function or the Elektron devices (Analog Four MKII - Synth | Elektron, n.d.) step-based parameter locking, but in most cases these self-sequencing

capabilities are simplified and limited in comparison to dedicated sequencers such as a software-based DAW. The renewed use of modular synthesisers foregrounds another approach where an instrument is as equally involved in the formation of musical structure as it is in the production of sounds and modification of timbre. Given the dominance of MIDI and its inherent separation of sound and musical structure generation over the past 40 years, this shift is significant.

The Eurorack Format

While many modular formats seem to have benefited from the increased interest in modular synthesisers, the Eurorack format has had the greatest expansion of module designs, new manufacturers, and users. The Eurorack format is serviced by hundreds of manufacturers, ranging from small operations offering one or two module designs through to large established companies such as Roland and Moog. This phenomenon of so many individual companies developing compatible modules for a common format is a significant shift from the origins of modular synthesisers, where formats were associated with a specific company such as Moog, Buchla, Serge, and E-mu Systems. The phenomenon is not exclusive to Eurorack, as other formats such as 5U and Frac also have participating companies; however, these operate on a significantly smaller scale in comparison to Eurorack.

The participants reported that designing and working with a Eurorack modular system is significantly different from working with a single manufacturer format such as Buchla, Moog, or Serge. They correlated the experience of a single-manufacturer format as being more defined as an instrument. Working in the Eurorack format enables a musician to specifically tailor their instrument to their intentions. This may have contributed to the participants' experiences of continually modifying and refining their instruments; new modules suggest new ideas being foregrounded, thus necessitating other changes to the instrument. The impact of overlapping design ideologies has already been discussed, but I note it again here because it involves a significant diversion from earlier modular formats.

While all modular formats seem to retain or increase their resale value over time, the range of modules available for the Eurorack format, along with the very large user base, contributes to a particular liquidity for Eurorack modules. The participants reported regular transactions of selling and buying modules, sometimes after only owning a particular design for some weeks. As has also been my experience, they reported selling particular modules, only to re-evaluate their usefulness and repurchase the same design again. This aspect of Eurorack could be interpreted as eroding the instrumentality of the instrument, because instead of working with and around its perceived limitations, the musician is simply removing

that component altogether, presumably with the intention of replacing it with something that they hope is closer to their own needs. However, the potential to refine and specify the modular instrument's capabilities might also be interpreted as a way to deliberately define and delineate its limitations and thus arrive at a more particularised or distinct instrument.

Community and the Internet

Histories depicting the development of modular synthesisers in the 1960s and 1970s highlight the influences of social interactions and collaborations. Moog consulted broadly with a range of composers when developing his instruments, and Donald Buchla's design came from collaborations with Ramon Sender and Morton Subotnick (Bernstein, 2008; Pinch & Trocco, 2004). The Serge instrument was developed within a social educational setting at the California Institute of the Arts (CalArts) and first manufactured in a collaborative workshop environment. The high cost of modular synthesisers in this period meant they were more likely to be encountered in universities and colleges than in private home studio settings.

Following the advent of the internet in the early 1990s, special-interest communities were able to connect via listservs and online forums that enabled near-instantaneous exchanges. Along with the increase of interest in electronic music and electronic instruments throughout the 1990s, a range of online communities emerged that focussed on analog electronic instruments, specifically modular synthesisers. This networking effectively magnified the experiences, designs, and approaches that would otherwise have resided in the social connections of those who had direct experiences of rare, expensive, and esoteric instruments.

Legacy Designs and Concepts Revisited

One impact of this networking was that a range of module design concepts was brought forward and accessed by musicians and designers who may not have had first-hand experience with the instruments associated with these concepts. An example is the range of modules offered by Doepfer, who established the Eurorack format. The A-100 modular synthesiser was first offered in 1996 (Vail, 2014). In 2001, a Yahoo Group was established where users (and potential users) could interact with each other and with Dieter Doepfer and other staff from his company to discuss modules and suggest improvements or new designs (Doepfer_A100 - Archive of Yahoo Group, n.d.). A discussion about the use of sample-and-hold or track-and-hold functions as a means to recreate analog shift registers led to the

design of the Doepfer A-152 module, with its functions largely defined through that group's discussions.

Web-Based Resources

Any given module design is likely to be accompanied with a plethora of documentation and media, some produced in connection to the module manufacturer, others contributed by independent users and enthusiasts. The participants discussed using web-based materials as they researched possibilities for their own instruments and processes, including patching techniques and esoteric module designs. They accessed forum posts from users and manufacturers, video interviews with module designers, marketing materials, video reviews, tutorials for individual modules, PDF manuals, direct email discussions with particular designers, and discussions on social media. They also described researching particular instruments or techniques and then incorporating their key affordances into their own instruments.

Digital and Analog in the Modular

A modular synthesiser is inherently an analog system. Control voltage is an analog signal, and connections made between modules, even between two predominantly digital modules, are necessarily analog in nature. Gates and triggers are binary signals and, depending upon one's interpretation of the term *digital*, an argument can be made for that component of a modular synthesiser to be considered digital in nature. However, in the interest of discussing the phenomena associated by the participants in relation to their use of digital and analog components, in this context I will persist in differentiating between analog and digital on the basis of the use of programmable chips and digital signal processing (DSP).

The heritage of the modular synthesiser is undoubtedly analog but advances in digital signal processing have opened up possibilities for digital components to be embedded within a modular synthesiser. The Buchla 200e system, a modernised version of the Buchla 200 format, released in 2004 (History | Buchla, n.d.), took the radical step of completely digitising some internal components, including oscillators, and providing digital control over the remaining analog signal paths. This enabled the Buchla 200e to save and recall the settings for each module, but the instrument was still reliant on physical patching to determine the control and audio signal pathways. Due to the analog nature of a modular synthesiser's patching paradigm, all components are effectively analogised within the environment through the use of digital-to-analog converters (DAC) and analog-to-digital converters (ADC), for both audio and control voltage signals.

Eurorack and Digital Modules

The emergence of Eurorack as the pre-eminent modular synthesiser format between 2005 and 2010 coincided with the availability of small, cheap, and increasingly powerful microcontrollers and DSP chips. The release of programmable devices such as the Arduino platform (Arduino, n.d.) enabled amateurs to program functionality that interacted with the broader world via motors, lights, LCD screens, sound, and various sensors. Many of these digital processors, including Arduino, have made their way into Eurorack modules to perform a range of functions. Of the participants I interviewed who use the Eurorack format, all had at least one digital module, and some were almost entirely reliant upon DSP-based modules.

Digital Essence

The degree to which a module reveals its digital nature varies greatly, with some modules effectively carrying out a function that could be achieved using analog circuits, such as a clock divider, and others offering fully programmable environments capable of audio and control voltage processing. The presence of screens, menu trees, continuous encoders, preset recall, or multifunctionality brings the digital nature of a module to the foreground. A module might also offer a single defined function distinct to digital processing, such as digital reverb, FM synthesis, or audio sampling without any reliance upon screens or menus, effectively presenting an interface and an affordance identical to those of an analog module.

Digital and Flow

The participants noted their experiences of modules whose digital nature was foregrounded through screens, menu trees, and multifunctionality. They identified requirements to navigate settings in a menu tree or to load or save data such as samples or presets as processes that would pull them out of a flow experience with the instrument. The need to check a manual to understand how to operate or change settings, often buried within a small screen or special button combination, caused them to step back from listening, performing, or experimenting.

Multifunctionality and Permanence

Some modules offer many different modes of operation. For example, the Expert Sleepers disting EX v1.11 firmware manual (Expert Sleepers Disting EX, n.d.) lists 14 distinct modes of operation, from granular processing to matrix mixing and switching. To encounter a disting module in a modular case reveals little of the function the module might be performing. From the musician’s point of view, the disting brings a large degree of flexibility to their case, allowing for a range of functionalities to be incorporated in very little space; however, this also erodes the instrument’s permanence by shifting it closer to the ambiguity of a software-

based approach. Some participants found this ambiguity challenging and would avoid these types of modules, while others fully embraced them. The nature of the disting's interface may also be a factor as it must enable interaction with a range of devices, preventing the interface from representing or supporting any one function.

Software in the Modular

Some participants found that the potential of digital modules to embed functions such as granular synthesis and complex function generation and recall enabled them to bring their computer-based practices to the modular instrument, effectively retaining the best of both worlds. New possibilities also emerged; for example, the embedding of an FM synthesiser engine in a modular environment allows a range of new possibilities when compared to an FM synthesiser as a stand-alone instrument only controllable through MIDI.

The Modular Lens

The participants reported that their use of modular synthesisers shifted their perspectives on electronic music processes, changing their intentions for music making. The most obvious manifestation of this experience was the shift in the initial intentions of the participants when they began using a modular synthesiser for the first time. Many said their initial intention for engaging with modular synthesisers was to access "that analog sound" or to construct a customised synthesiser voice. Some envisaged the control of the modular synthesiser to be undertaken through MIDI or a DC-coupled computer audio interface so that musical structure generation would almost entirely reside in the existing workflow of their computer-based DAW or external sequencer, with the role of the modular synthesiser limited to the generation of timbre. In many cases, their intentions dramatically shifted as they were drawn into the possibilities for a modular synthesiser that controls itself through complex systems and sequencing components.

The participants ascribed value to this transformation of their practice, some even returning to computer-based composition systems with new approaches drawn from their experiences with modular instruments. This phenomenon suggests that what is valued in the use of a modular synthesiser is not only the experience of working with a physical instrument, but also the ideas and processes that are embedded within the modular instrument but not reliant upon the modular instrument paradigm to be enacted.

Concluding Discussion

Having identified a gap in the scholarly research in supporting an understanding of the resurgence of the modular synthesiser from the musician's perspective I set out to explore and describe how modular synthesisers are used, determine how the experience impacts upon the processes of music making, and show why the experience is valued by musicians. The four essences described in this chapter – instrumentalising the studio, modular synthesisers as compositional tools, discovery and co-creation, and the contemporary modular synthesiser – offer coherent and unified accounts which shed light on the resurgence of the modular synthesiser in contemporary musical practice. This chapter has shown that the desire for and discovery of a new and flexible manifestation of the instrument, new or rediscovered approaches to composition, openness to a more complex relationships with compositional and performance systems, integration of digital processes within modular systems, and new forms of community are at the heart of this resurgence.

Conclusion

The contemporary resurgence of the modular synthesiser marks a significant deviation from the dominant paradigms of electronic music instruments and technologies that have lasted more than 30 years. It thus presents a rare and significant opportunity to better understand musicians' experiences with electronic music instruments. This project has sought to understand this phenomenon from the perspective of musicians who work with modular synthesisers by capturing and analysing their reflections on their experiences in order to explore and describe how modular synthesisers are used, determine how the experience impacts upon the processes of music making, and show why the experience is valued by musicians. Descriptive in nature, its intention was to establish a broad array of rich thematic descriptions, grounded in the diverse range of these musicians' lived experiences.

I have engaged in some depth with methodological questions and include in this dissertation considerable discussion of the phenomenological research approach and specific inquiry methods utilised in this research. This attention to methodology provides me security regarding the validity of my inquiry processes and the specific findings of the inquiry.

Key Findings

Through discussion and analysis of the thematic descriptions, this dissertation has constructed an argument for a set of understandings that have significance and relevance beyond the phenomenon itself. The resurgence of modular synthesisers demonstrates a desire among the participating musicians to (a) configure all elements of an electronic music studio into the instrument, (b) generate musical structure in real time, (c) experience a sense of discovery through a sharing of agency with the instrument, and (d) enable new understandings of modular synthesisers in the contemporary context. These findings will now be discussed.

Instrumentalising the Studio

The use of the modular synthesiser to bring aspects of electronic music production into the context of an instrument with limitations and a physical form that can be learned and performed upon challenges the distinctions typically made between sound-producing instruments and recording and production equipment such as mixing desks. This use reflects

the motivation for the design of the first modular synthesisers, which was to enable the real-time and performative possibilities of tape music practice.

The modular synthesiser paradigm, with its inherent possibilities for customisation and flexible routing, enables components of the music studio to be approached by an instrument. The musicians interviewed for this study indicated that the modular synthesiser enables this to a greater degree than a combination of software and dedicated controller. A related phenomenon might also be observed in the design of software titles like Ableton Live (Ableton Live Website, n.d.) and its associated control surfaces, where the processes of recording and arranging audio and MIDI are presented as real-time and performable.

Modular Synthesisers as Compositional Tools

The modular synthesiser brings with it a range of techniques and approaches to composition that exhibit unique qualities when compared with other paradigms embedded within fixed architecture sequencers or software-based DAWs. The research subjects described the real-time generation and manipulation of musical structure, in combination with the possibilities for this to be performed and improvised upon, as substantial shifts in their experiences of making electronic music. Similarly, they reported the shift away from a timeline and a quantised grid, along with the emphasis upon real-time processes using complex systems, as positive components of the modular synthesiser experience. Interestingly, the participants did not report this aspect of using a modular synthesiser as an initial driver for their exploring modular synthesisers, but was instead one that arose through their experiences of using the instrument. They then maintained and built their interest beyond their initial encounters.

The participants reported that their experiences of both the compositional processes and the outcomes arising from those processes were unique and positive. When these descriptions are examined in conjunction with other descriptions that situate the modular synthesiser as an instrument that is unable to save or recall its state, another possibility emerges. The modular synthesiser also facilitates a more authentic experience of performing electronic music by allowing, or even forcing, a level of open-ended compositional processes to occur live, as opposed to the performative reconstruction and arrangement of music from precomposed elements that are often characterised as live electronic music.

Discovery and Co-Creation

The participants described their conscious and deliberate decisions to use the modular synthesiser to experience the sense of discovering unexpected but interesting outcomes.

Essential to these experiences of discovery was a handing over of agency to the instrument, allowing decisions to be made through automated systems or by invoking complex processes, the outcomes of which could not be predicted. Each participant's "work" as a composer became focussed upon the definition of boundaries and the shepherding of possibilities towards aesthetic ranges. These processes occurred in the design and the patching of the instrument, and in the performances and improvisations with it.

The sharing of agency with the instrument is precise and judicious. Managed by the composer at every step and revoked once the system strays too far from their aesthetic interests, the sense of authorship is retained. Where agency is given over in the specification and management of precise musical events, it is gained at grander scales as small adjustments to complex systems affect the character and density of whole passages. In this way, the overarching trajectory of the resulting music is defined in broad strokes.

The participants described their intentions to explore possibilities and have their music shaped and changed through their use of the instrument. This contrasts with the commonly assumed benefits of technology that situate the musician as the empowered decision maker whose ability to realise their ideas is amplified, such as the relative convenience of creating any sound and of realising multi-layered compositions.

The Contemporary Modular Synthesiser

The design impetus for the earliest modular synthesiser – to make the possibilities of a tape music studio performable in real time – remains a key aspect of their valuation and use by musicians. For some musicians, a better alternative has not been presented in the intervening decades since their introduction in the mid-1960s. Observations drawn from the findings of this project also emphasise the contemporary context of the modular synthesiser resurgence, drawing attention to aspects of the phenomenon that are only possible, or observable, in the present-day context.

The situating of digital module designs in the context of an analog paradigm allows for comparative experiences and descriptions that complexify our understanding of how technology may be used in a music-making context. This goes beyond the classic dichotomy of analog being regarded as 'warmer' and digital being 'colder but more precise'. The participant's experiences of digital components in a modular synthesiser revealed issues around the identity and permanence of the instrument and its impact upon the experience of flow.

Another factor unique to the contemporary context is the internet, which from its introduction in the 1990s has supported a range of specialist communities interested in modular synthesisers. These networked communities have enabled designs, compositional processes, and histories to be shared with ever-larger audiences, and they are likely responsible for a range of idiosyncratic and otherwise esoteric approaches to electronic music becoming embedded in module designs that have since been manufactured in large numbers.

The most popular format for modular synthesisers, the Eurorack standard, is an example of a marked difference from earlier modular instruments. With hundreds of manufacturers and thousands of modules available, it is common for a musician to curate an instrument that draws upon a broad range of instrument design ideologies rather than a single company's offering. This selecting from and overlapping with a range of designer’s ideas is unique to the contemporary experience of using a modular synthesiser instrument. The range of modules available also enables a musician to create highly specialised instruments tailored to their own interests and approaches, or even to a specific composition.

Perhaps most significant of the observations enabled by the contemporary modular experience is that it is transformative. The participants’ interests in their instruments began with specific intentions, but they experienced shifts in these intentions and interests through their use of the instruments. This transformative process was highly valued by the participants. In some cases, when they had returned to using a computer to create music they reported that their approach had shifted dramatically due to their prior use of a modular synthesiser.

Further Research, Implications, and Limitations

These findings suggest further research in three areas: related to modular synthesisers directly, the design of other electronic musical instruments, and human creative processes in relation to technology.

While many of the thematic descriptions presented in this thesis identify processes and approaches that are unique to the experiences of the participants in this study, the key findings describe significant aspects of the resurgence of modular synthesisers that can inform musicologists, instrument designers, and marketers alike. However, the findings also raise questions that alternative research designs may be able to address. Despite the

diversity of modular synthesiser use, future quantitative studies may attempt to measure the comparative extent of the various drivers for their use.

While this research project offers rich, thematic descriptions of the lived experiences of using a modular synthesiser, its scope did not extend to measuring the comparative extent of various drivers for their use. A quantitative research instrument could be designed to use the key experiences identified and to measure and identify the comparative degree to which these might apply to a more representative sample population.

It may be possible for future instrument developers and marketers to draw on the findings of this research to enable similar experiences in the use of fixed architecture instruments. Potential lines of inquiry include:

- Increasing the possibilities for the manipulation and generation of musical structures.

- Closer integration of audio and control signal parameters and of alternatives to the traditional, timeline-based representation of musical events.

- New understandings of human-machine interactions and interface designs by drawing on theories of embodied and environmental cognition and on the impact of physicality upon processes of complex system-building.

Summary

For a technology that was so deeply entangled with technical possibilities in the 1950s and 1960s to become effectively obsolete only to once again be commonly used is historically unusual. This study has revealed that the resurgence of the modular synthesiser may be characterised as a contemporary approach to the electronic musical instrument that blurs the lines between real-time composition and performance. It opens a space for musicians to co-create or discover new forms of musical expression in partnership with the instrument and it breaks down the barriers between digital and analog systems. While nostalgia and a desire for “that analog sound” appeared as factors in the initial interest of some of the project participants, the drivers that sustained and developed their use of the instruments are far more complex. The possibilities for the real-time, authentic, and improvised formation of musical structures hark back to the original intentions in the design of the modular synthesiser.

This resurgence provides a correction to the trajectory of electronic music technology, which, through the introduction of MIDI and the standard application of a keyboard to control synthesisers, has created a distinct separation between sound generation and musical event generation or composition. This separation has assimilated the emerging field of electronic music into the pre-existing paradigms of music making, where the playing of an instrument and the creation of musical structure are largely considered distinct processes. The compositional aspects of the modular synthesiser allow the music maker to combine musical structure and the generation of sound in ways that can be performed and improvised.

Glossary

These terms are used throughout with the following definitions

Control voltage (CV)
A signal used to control a parameter of another module. Typically 0-10V following the 1V per octave standard. Modules may also be designed to respond to bi-polar control voltages allowing the use of audio signals as control signals.

Envelope Generator (EG)
A modulation source that is triggered rather than oscillating continuously. Typically consists of 2 or more stages with each stage denoting a rise or fall in voltage level over a period of time to enable the shaping of volume, filter level or other properties of a synthesised sound.

Gate/trigger
An instantaneous rising or falling voltage used to trigger the start and end of an event respectively. Typically 0 - +5V or -5V - +5V

Generative Composition
A broad term that encompasses any rules-based system utilised for the creation of music (Collins & Brown, 2009).

Low-frequency oscillator (LFO)
A signal generator that produces voltage oscillations, usually offering a variety of waveform shapes including square, sine, sawtooth and triangle. Low frequency oscillators are designed to operate at slow rates of oscillation beneath the threshold of human hearing typically ranging between several oscillations a second, down to oscillations over a period of a minute or longer.

MIDI Control Change (CC)
A specific form of MIDI information that enables specific parameters to be adjusted in an electronic instrument externally. For example a filter cut off.

Music Instrument Digital Interface (MIDI)
A defined industry standard developed in the early 1980s to allow electronic instruments to be controlled by, or control, other devices such as sequencers or computers.

Modular Architecture
A modular architecture is a system that supports the co-location of various components or devices adhering to standards that enable additive functionality and interoperability (Gentile, 2013).

Modular Synthesiser
An electronic musical instrument having three principal features: (1) multiple independent components that can be configured together in a range of ways; (2) the use of a method of

voltage control; (3) the creation or modification of sound in real time (Dalgleish, 2016; Elsea, 2013; Pinch & Trocco, 2004).

Module
Individual components designed to be co-located with others to enable the exchange of electrical signals, usually via the connection of patch leads for the purpose of producing sound or other electrical signals.

Patch
A particular configuration of a modular synthesiser using patch leads to create connections between modules using control voltage (CV).

Sample and hold
A device that can sample an input, when triggered by a trigger or gate signal into another input, producing the sampled CV at its output. When the next trigger is received at the second input it updates the output to again match the sampled input CV value.

Stackable cable
A 1/8 inch jack cable that allows another 1/8 inch jack to be connected on top. This allows multiple signals to be routed from a single point.

Synthesiser
“An electronic instrument used to combine, create or modify sounds” (Cambridge Dictionary, n.d.).

Voltage addressed switch
A device controlled by CV that routes signals from one or more inputs to one or more outputs.

Creative Practice Appendix

Digital files for each are provided:
https://www.dropbox.com/scl/fo/374824qxks2lr16ohjk5u/h?dl=0&rlkey=z6kehk48ejumfmoveomdfllrc

Audio example 1: Terrible things have happened to MIDI, April 2021

Self published release available as audio tape, digital file, April 2021.

https://alexewhite.bandcamp.com/album/terrible-things-have-happened-to-midi

1. In a room without windows 00:40
2. Now do you see 06:24
3. On an empty afternoon 04:54
4. Terrible things have happened to MIDI 10:31
5. There are only names 05:17
6. There is no memory of how this occurred 09:24

https://www.dropbox.com/scl/fo/8ueliu5b2bc6gz4vlsu9l/h?dl=0&rlkey=sd8hds8a45hp5vsy63pyckfe8

Audio example 2: *Five Unknowns, Certain Situations* Exhibition, Agatha Gothe Snape and Wrong Solo, June 2019

Commissioned composition for the artwork *The Five Unknowables,* in exhibition *Certain Situations* by Agatha Gothe Snape and Wrong Solo at the Institute of Modern Art, Brisbane, 29 Jun–31 Aug 2019

https://www.ima.org.au/exhibitions/agatha-gothe-snape-certain-situations/

1. Gallery soundtrack loop 2:00:00
2. Binaural recording of performance by Wrong Solo with accompanying music 10:12

https://www.dropbox.com/scl/fo/czk8nli4xd1v5sldx6zyg/h?dl=0&rlkey=nhr86hlf2ln4qkjmca38fi985

Audio example 3: *Transductions,* June 2020

Digital release, Room40, June 2020

https://room40.bandcamp.com/album/transductions

1. Cheekbone Against Window Of Car 02:51
2. Slow Descent Of Wooden Window 1:08
3. Cheekbone Against Window Of Train 07:44
4. Bicycle Rear Wheel Lateral Movement 02:26
5. Large Tent In Mild Windy Conditions 05:32
6. Palm Pushed Against Cold Metal Handrail On Stairway 09:57
7. Water Hammer 08:27
8. Ear Canal in Car with One Window Open 02:54

https://www.dropbox.com/scl/fo/1dibw2nt1ph8sbrcd5el4/h?dl=0&rlkey=kfzm971z08i0btphid9ewm7it

Audio example 4: Steep St performance April 24 2021

A truncated excerpt of my performance at Steep St Artist Run Initiative on April 24 2021

1. Steep St performance excerpt 05:26

https://www.dropbox.com/scl/fo/21rs5ix3jdliue1qempoy/h?dl=0&rlkey=wiofgh9b9t20swh0l7nwqiv75

Audio example 5: Warehouse performance May 28 2021

A truncated excerpt of my performance at an inner Sydney warehouse May 28 2021

1. Warehouse performance excerpt 09:10

https://www.dropbox.com/scl/fo/oi6fvl4qeoa238d7mz2i5/h?dl=0&rlkey=8hvzgwo7vf6liyk04vkzpv6td

Audio example 6: Warehouse performance April 7 2022

A recording of my entire performance for Liquid Architecture Mono Poly on April 7 2022

1. Liquid Architecture Mono Poly performance 31:52

https://www.dropbox.com/scl/fo/f2xnd2ujojl4dhq2sjuo7/h?dl=0&rlkey=ldvoy784o52dv41zdpfy29zkc

Audio example 7: After Dark, Sydney Living Museums, Hyde Park Barracks, June 30 2022

A truncated excerpt of my performance at Hyde Park Barracks for Sydney Living Museums June 30 2022

1. After Dark performance excerpt 05:13

https://www.dropbox.com/scl/fo/noqbqldrfxmqn3xi6ofra/h?dl=0&rlkey=d4i40urkpzamanax7vx5bxj41

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