Conception to Construction:
Compositional decision-making informed by theories, patterns and processes in the physical, life, and computer sciences.

Z LEEMING

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Conception to Construction:
Compositional decision-making informed by theories, patterns and processes in the physical, life, and computer sciences.

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A portfolio of original compositions and thesis submitted in fulfilment of the requirements of the Royal Northern College of Music and Manchester Metropolitan University for the degree of Doctor of Philosophy

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ABSTRACT

This critical commentary presents my compositional research investigating how theories, patterns and processes in the physical, life and computer sciences have informed my practice. Engaging with the work of composers who have explored related ideas in their work from Xenakis and Ligeti, to Emily Howard, Robert Laidlow and others, this research considers different understandings of the meaning and role of 'science' within an artistic practice.

I reflect on the methodologies that have emerged as proxies to navigate my interest in scientific concepts within the language of music, including metaphor and collaboration. Scientists involved in collaborations within this project include biochemical engineers and chemists from Manchester Metropolitan University and the University of Liverpool, and doctors and health data scientists of Connected Health Cities (CHC) and the International Severe Acute Respiratory and Emerging Infection Consortium's UK Covid-19 group (ISARIC4C).

The thirteen works that complete the portfolio track the development of my compositional voice in conjunction with the progression of this research over the degree period, and investigate the topic through structural musical, interaction-based and technological exploration including the use of electronics, augmented instruments, video, and machine learning technologies alongside a broad range of instrumental ensembles.

This practice-based research also considers historical and philosophical discussions on the meaning and role of science from the classical era through to the modern scientific method, engaging with Karen Barad's theory of agential realism and Donna Haraway's posthumanism to present a view beyond C.P Snow's 'two cultures' (1959).

Concluding with reflections on my compositional practice and the developing area of composer/scientist collaborations, this commentary investigates how this body of work contributes new knowledge to this field and discusses the impact legacy of the work itself.

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CHAPTER 1

INTRODUCTION

This chapter provides an introduction to the aims, definitions and rationale of the core topics of the research. How my practice responds to these will be explored in the research methodology provided in Chapter 2, and the wider research context including a practice review is detailed in Chapter 3. Chapters 4 – 6 explore the individual works of the portfolio, grouped into themes arising from the research contextualisation, with Chapter 7 reflecting on the conclusions to this body of work.

i. RESEARCH AIMS

The primary aim of this research is to create new works, sometimes in collaboration with scientists, that explore how compositional decision-making can be informed by theories, patterns and processes in the physical, life, and computer sciences. My relationship to science, and reasons for exploring this research area are examined, as are the wider social and historical meanings of science as well as its changing cultural status and roles throughout time, particularly in relation to music. Whereas strategies such as sonification and more systematised methods of responding to science in music are well represented in the existing literature, this body of work aims to reflect on, and provide context to, approaches that allow for a more poetic, or indirect manner of responding to these extra-musical ideas. Through collaborating with scientists, this project aims to uncover new approaches to collaboration within my composition practice, as well as inviting the possibility of cross-influence between our disciplines. By conducting each of these explorations through a variety of compositional tools, scoring methodologies, technology and other media, this body of work seeks to survey a range of tools and strategies available to artists wishing to explore critical areas of discussion in this developing inter-disciplinary field. By doing so, this creative project and commentary aims to contribute new knowledge to the fields considering extra-musical composition

strategies with specific reference to science and composer/scientist collaborations, in order to continue a legacy of communication between the sciences and the arts in the current era.

ii. SCIENCE & MUSIC – Definitions and Scope

"Science" is no single thing: its boundaries are drawn and redrawn in flexible, historically changing and sometimes ambiguous ways (Gieryn, 1983, p.781).

The term 'science' can refer to many things, including the methods and products (knowledge and technology) that are associated with the term today, as well as its historical meanings and social roles, all of which were explored through the portfolio. Both the definition and practice of science has changed over time, and of these changes, together with the philosophies underpinning them, were explored in the portfolio. For instance, *Scaffold II* includes an internalised dramatic element informed by demonstrations at The Royal Society during the transition between natural magic & experimental philosophy, with *Mark 1* exploring a similar, but externalised dramatic element informed by the current scientific method. Some works explore knowledge-products, such as *Surface*, written with regard to a phenomena causing fluid to travel upward along surfaces known as the *Gibbs-Marangoni* effect. Other works take scientific processes as a source of influence (the aforementioned *Mark 1* – see Chapter 4), whilst others draw from a scientist's account of the challenges and solutions they discovered (*Waterwheel, Rennervate* explored in Chapter 5). *A Length of String* is informed by the consideration of acoustic properties, and lastly, later works explore new technology made available, such as machine learning tools (*Sad Dog Eating*). The work-series in Chapter 6 – *Aubergine Soup Tourine* – engages with philosophical responses to significant scientific issues of the current era, such as notions of reality after the quantum eraser experiment (Barad, 2007), as well as imprudent use the products of science and technology as a cause of resource scarcity and climate change, leading to the need for new approaches (Haraway 2016). The works in this series consider the role of science in shaping our modern world, engaging with ideas of hybridity, technological augmentations and digital performance environments.

This body of work therefore draws from a constellation of meanings, processes products of science as well as philosophical responses to each and the changing positioning of science and music within both academia and wider society, beginning with classical attitudes maintaining connection between these now independent disciplines (Illiano, 2019, pp. iii–xiv), through to their eventual estrangement as described by C.P. Snow's seminal lecture (1959), arriving at the resurgent interest in science within the arts in the current era.[2]

The synthesis of this theory with practice in the portfolio is demonstrated in the increasing consideration given to the material agencies and social roles explored in the construction of works, (e.g. the increasing space for performer choice and ensemble authority in directing responses to scores in *A length of String, Mark I, At the Node of Ranvier* and others*)* as well as engagement with the developing discussion of entanglement, reality, and hybridity in the information age (e.g. *Output VI, Sad Dog Eating*).

The reason for exploring historical and philosophical challenges to science within this artistic project is to reflect the ever-developing nature of the term and its use, and by doing so, to prevent internal contradiction in the aims and body of this work – by recognising that the 'science' described herein may one day no longer be considered to be, well, very *scientific*.

iii. RATIONALE – Why Science & Music Merits Artistic Enquiry

Between the products of nature and those of art no essential difference prevails. – Anton Webern (Griffiths, 1992, p. 98).

[2] Aided by a simultaneous move to readdress notions of reality in social theory following its deconstruction during the postmodernist era (Barad, 2007), and evidenced by the creation of new dedicated centres of research seeking to re-esablish links such as RNCM's Practice & Research in Science & Music.

In an age where science in all its aspects; authority, processes, knowledges and enabled technologies, all factor more highly in so many day-to-day lives, there is a surprising lack of direct artistic inquiry into this topic in a general sense.[3] While there is a strong tradition in composers and scientists working together to solve acoustical problems such as tuning systems, and the production of complex overtones (Benson, 2007, Chapter 5) or to collaborate for the purpose of music informed by certain knowledge-products (such as György Ligeti and mathematician Heinz-Otto Peitgen's relationship whilst the composer was exploring dynamical systems (Peitgen, 2011)), there is no comparable body of work investigating the nature, processes and meanings of science in music as there has been for say, literature, visual arts, the human condition, beauty, and religion. Architecture and mathematics stand out as two sub-fields of science for which there is an associated musical body of work and complementary literature,[6] the first possibly due to its blend of visual art, space, embodiment and temporality – all well-developed areas of artistic investigation – and the second due to its well-documented suitability for symbolic exchange and inter-relation.[7] But there are few investigative projects that provide a wide-lens view of the sciences as an artistic subject matter or include within the frame the nature of the knowledge-systems themselves.

Another reason to pursue this topic was referenced in the aims: to explore why been drawn to engaging with ideas associated with science in my practice. Discovering other composers'

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[3] As opposed to use of individual technologies afforded by scientific developments, such as augmented instruments or machine learning, or specific areas of mathematics such as chaos theory, fractals, etc.

[6] For a contemporary response to architecture by a composer, as well as a survey of the field, see the PhD thesis of Emma Ruth-Richards (2014). For reference to a body of literature on composers engaging with maths, a good starting point is Illiano & Locanto (2019), and for contemporary practice, the music and writings of Emily Howard.

[7] 'Given that a Western composer has to deal with musical parameters that admit quantification in a way […], the presence of mathematical thought is almost ineluctable. In particular, the symbolic value of Western musical notation has been historically fruitful for those sorts of mental operations and has thus embodied their representative potential' (Besada, 2019 p.263). Also: 'Music and mathematics share a very close relationship. If we consider that the meter of a piece is represented by a mathematical fraction, we can then understand how profound this relationship is' (Illiano & Locanto, 1999, p.ix).

reflections on the same has to some degree sufficiently answered these questions. As previously mentioned, subjects such as beauty, religious feelings, as well as love, and the notion of the sublime are all well-established areas of artistic enquiry. Upon reading the exchange between Olivier Messiaen and Iannis Xenakis at the latter's own thesis defence (1985) quoted below, I realised the forces driving other composers to explore such topics listed above directly, were the same reason I was drawn to science. Far from being the dry subject matter some assume, or a topic somehow at odds with the proper nature of music[9] an artistic investigation into the nature and meaning of science is at its heart, nothing short of an inquiry into the nature and meaning of our experience and understanding of life itself. Since *that* is easy to understand as artistic pursuit, it seems surprising that science and music is not immediately obvious as a topic that merits more extensive and varied artistic scrutiny than it has received to date, especially considering that unlike philosophy or literature, the scientific method currently occupies the highest position of authority in the knowledge-production hierarchy of our age.

The following conversation, I believe, outlines what appears to be a rarely challenged assumption: the reason some composers are drawn to the exploration of scientific subject matter is to distance themselves from ideas of emotional and spiritual connection with their reality, when the opposite may well be true.

Messiaen: Having studied theology, I can apply this ['being' as referenced by Xenakis to a quote by Parmenides] only to God, since only divine attributes are expressed. Yet, you explain this text in terms of energy and energy conservation… I cannot love the things within this sound which are so refined that I cannot totally perceive them…but I accept the whole, in itself, since I am attracted to that. You are attracted, therefore there is a revelation!'

[9] Even those who enjoy both music and science appear unconvinced: '"Scientific" music has not, however, always been appreciated by musical scientists' (Field, 2006, p. 11). The authors continue to outline Christiaan Huygen's disdain for what he described as structures that are 'artificial' and 'difficult to invent', articulating 'the tension between 'scientific' construction in musical composition, on the one hand, and expressive effect, on the other.'

Xenakis:	That's right, yes.
Messiaen:	A revelation is like falling in love, like a thunderbolt. It's the Romantics' *inspiration*.
Xenakis:	Yes, I don't deny that at all. On the contrary.
Olivier Revault D'Allonnes:	I didn't know you were a romantic, Iannis!

(Xenakis et al., p. 35)

i. Excluded topics

One significant exclusion from this Portfolio are works that engage directly with mathematical topics. The reason for this is two-fold. Firstly, the collaborations that form a major part of this research were driven by the research specialisms of the scientists. Secondly, and related to the first, principles that emerged from the research moved the portfolio away from general investigation and toward biological, chemical, and health-related topics, which enabled a focus to emerge on the type of new knowledge that this research could provide. As previously noted, mathematics and music share a uniquely close relationship, a topic for which there exists a vast body of work by composers, musicologists, and mathematicians. Had the opportunity emerged through the collaborations to engage directly with this topic and history, I would have embraced that direction. However, given the breadth of topics covered in the Portfolio, and my awareness of the role of mathematics and music as evidenced in practice review, I did not feel it required further exploration through individual works. A key insight that emerged from this research was that there is a vast amount of room remaining for new artistic research in all areas of science, particularly those that do not invite obvious quantification.

CHAPTER 2

RESEARCH METHODS

This chapter provides context for the methods used to explore a relationship between compositional decision-making and science, namely: collaboration, metaphor, and narrative in music. The definitions of these terms are discussed, as are their relevance to the portfolio. To situate these uses within the wider field, contemporary practice that explores similar methods is discussed, with a wider account of composers engaging with science provided in the practice review (Chapter 3).

iv. Musical narrative, metaphor, and programme: distinctions

Programme music is a category of aesthetics, not of biography. The decisive factor is not whether a composer has been moved by extramusical impressions, be they real or literary, but whether he has decided that the extramusical elements, be they expressed in the form of a programme, a motto or a title, should be part of the object itself, should pertain to the work as a musical entity (Dahlhaus, 1987, p. 100).

There are many answers for what constitutes 'programme' music. The definition most helpful in interrogating the usefulness of the term within this research is the one provided above, with the caveat that by this definition, all works in the portfolio could be described as programmatic as evidenced by this commentary. To check off the qualifying factors: each work responds to an extra-musical idea; is defined as such; and this aspect is an important part of the work as a musical entity (or the work-concept) – demonstrable by the aims of the research it was written with respect to. Whilst all works may be programmatic in this sense however (each responds to an idea from science), some works also have secondary programme, such as an accompanying narrative or definitive sequence used in the composition of the work and expressed in its concert programme. Examples include *Waterwheel* and *Rennervate* – both written in response to a narrative as told by the scientist. These works fit even the strictest

definition of programme music, and are arguably *more* programmatic than works such as *Sad Dog Eating* and *[U]nusual [m]etals* which engage only with a conceptual narrative rather than an accompanying literary, or sequential one. As such, a distinction here is useful, and it follows that the only works described *as programmatic* in this commentary are those that reference a clear, secondary narrative such as a biographical account or accompanying literary narrative.

The distinction is useful, since the different types help illustrate their respective roles in responding to the science in its context. For example, Dr Andrews' research journey toward spun synthetic scaffolds (as opposed to the theoretically preferred parallel scaffolds), provided a dramatic narrative explored in *Rennervate*. This narrative was conceived to familiarise myself with this new scientific territory, and the human story itself provided a type of 'scaffold' for musically exploring the topic. Therefore, there are two *types* of programme at work. Both of which serve as structural elements that combine to create the form, in the sense described by Robin Walker:

> Form is a musical shape perceived in its totality after its unfolding in real time. This is not to be confused with structure, which is a describable pattern or design. We recognise a person subjectively as a personality, and physical characteristics play a part in this. However, ultimately we sense them as a form; the sum total of all our reactions and stimulated feelings. We may also define a person objectively as a structure in terms of limbs and vital organs, but this would not be their form, merely a description. The experience of form goes beyond words and beyond conventional analysis. (2001, p. 112)

The use of a biographical narrative as one (or more) structural elements within a work responding to science is not uncommon. Lynne Plowman's *Seven Dark Lines* (2016) takes a similar biographical approach to *Rennervate*, presenting a miniature character study of Scottish scientist and science writer Mary Somerville, in her own words. In 2020, composer and pianist Sarah Nicholls presented *12 years* (2018-2021), a result of a collaboration with climate scientists, describing the work as 'a journey for the audience, which starts with the headlines and ends with Greta Thunberg. On the way, we overhear phone calls between fictional characters as they also grapple with the news, urging each other to worry less or do more' (Nichols, n.d.). Composers who have mixed biographical and structural elements include

Emily Howard, whose *Ada sketches* (2012) imagines the inner world of the mathematician (Barbican, 2019), responding in large part to letters written by the scientist whilst using algorithmic procedures to determine elements of the work (PRiSM, 2020).

Theoretical research as explored in *Waterwheel*, that relates a relationship between soloist and ensemble to the concept is also seen in Robert Laidlow's *Warp* (2021). The composer engaged with the concept of an Alcubierre Warp Drive, which as Laidlow describes as 'a theoretical solving of Einstein's general relativity that can propel a spaceship to speeds near the speed of light without (technically) breaking any laws of physics.' On the relationship between the soloist and ensemble the composer expressed how he 'loved the idea of Joseph sitting in the middle of the orchestra with his own material while every instrument around him was stretched, crushed, warped and expanded like the fabric of spacetime itself in Alcubierre's thought experiment' (Laidlow, 2021b).

Narratives that arise either from the scientist, or the science that composers respond to are often found in works that address specific scientific topics. It is difficult to say whether any of the composers mentioned here would characterise their works as necessarily 'programmatic' in the sense given at the start of this section (namely, that it is an essential part of the work-object), and given the term's not infrequent pejorative use[10] together with its sometimes incomplete characterisation of a work that simply includes reference to narrative (of which there can be a wide variety), the term should probably be used with care. Feelings toward the term itself aside, when used in combination with other compositional decisions, programmes (narrative or otherwise) have proven to be a useful method for framing a scientific topic in a

[10] 'Programme music – the method of basing a piece of instrumental music on a text that is an integral part of the work and not just the immediate cause of its composition – has for some decades been in aesthetic disrepute, as if it signified an alienation of music from itself. In the late nineteenth century, with Liszt and the New German School, it represented the 'music of the future', but in the twentieth century it has been consigned to the past or condemned to the realm of light music' (Dahlhaus, 1987, p. 96).

way that is layered, giving rise to any number of structural combinations informed by the central concept.

v. Metaphor and Non-Programmatic Narrative

Regardless of secondary programme, each work in the portfolio was composed with reference to a non-musical idea. There are many terms that could be used to discuss relationship to non-musical considerations, such as *inspiration*, *topic*, *translation* and of course *narrative*, as just discussed its literary or biographical sense. When using the term more broadly, I prefer the term metaphor, since as Abbate argues, 'If we speak of music as "narrative" we realise that the word is metaphorical,' (Abbate, 1996, pp. x) since 'what musical element, structure, gesture, effect, or device is "narrative" a satisfying descriptive characterisation?' the author continues: 'all words about music are in a sense arbitrary: verbal constructions (themselves reflecting some cognitive configuration) placed upon musical reality that will seem, to a given listener, to assume a similar shape', and 'put another way, verbally couched interpretations of music are performances and can only be more or less convincing' (Abbate, 1996, pp. x–xi). Abbate therefore leaves it in the hands of the individual to decide which they find most convincing. Almén (2017) advocates a divorce between musical narrative and its literary ascendants, and instead offers the idea of a narrative native to music. The purpose is seemingly to make speaking to the musical narrative of *any* work possible, without the prolonged and often tangential discussion about the true meaning of the term in a musical context, as demonstrated by the discussion earlier. In this context however, I am referring specifically to the use of extra-musical elements invited to inform the composition process. In this sense, I would have to agree with the idea that in absence of 'referentiality, a subject-predicate relationship, a narrator, and a past tense' (Almén, 2017, p. 19), as well as direct forms of representation as might be found in visual art, narrative in music is primarily an applied isomorphism. Or to borrow a Butlerism, narrative is revealed to have been metaphor all along.

It would be redundant to here describe all the ways in which musical language can be used to construct metaphor, but to give a simple definition of the use in this body of work, it is the selection of parameters (pitch, rhythm, staging, instrument, performer actions, etc.), that have

been given roles in a system with inter-referentiality, that has been constructed with consideration of a non-musical object or idea. The system does not need to be *descriptive* of that non-musical idea, nor does the system need be concretely rule-driven, complete, or consistent. The system, or its effect may be impossible to describe via analysis. The only requirement is that a non-musical thought has led to the construction of another thought, which is musical. When operating in this mode, I consider myself to be composing music with a metaphorical mapping between two domains.

vi. Metaphorical Mapping – degrees and types

'Mapping' as the term is used within this commentary, is similar to the idea of Almén's 'mediation', developed from philosopher Charles Sanders Peirce's definition of signification, which involves:

> A triadic relation between a sign (that which stands for something else in some capacity for a particular community), an object (that which the sign stands for), and an *interpretant.* The interpretant is a rule of action that participates in a system of relationships through which any one sign is enabled to signify its object. In other words, there is no simple one-to-one relationship between sign and object. Instead, that relationship relies on its being distinct to some degree from various other signs that mean somewhat different things. In order to know what a sign signifies one has to see how that sign fits into the larger network of signification. (Almén, 2017, p. 42)

A single sonic event is often insufficient to describe an object or idea (whether considered 'purely musical' or otherwise), or to interpret this. The context of the work it sits within is usually required. This contextual interrelation can then be used to signify together with, or between realms. Whilst any such system is still only working in the realm of abstraction, or 'miming' (Abbate, 1996), two systems of invented signification can together create meaning through an isomorphic relationship (Jakobson, 1965, p. 29).

The mapping from one domain to another can be intuitive, but in the case of some sciences, such as mathematics, can be more direct. Susan Wollenberg (2006) argues that 'The

fundamental parameters of music – pitch, rhythm, part-writing, and so on – and the external ordering of musical units into a set, have lent themselves to systematic arrangement reflecting mathematical planning' (p. 8). Given the quantifiability of the features of both languages, these reflections can be made both ways. One example is the description of glissandi as a vector such that 'the scalar size of the vector can be given by the hypotenuse of the right triangle in which the duration and the melodic interval covered form the other two sides' (Xenakis, 1992, p. 13). Having ascribed mathematical parameters to the musical ones, operations can then be performed, the results of which can then transcribed back into musical language. The quantitative nature of both languages allows for this type of direct retranslation.

As mentioned in the introduction, the sciences explored within this portfolio do not always admit obvious quantification, thus a direct mapping strategy did not appear useful. Whilst it is arguably possible to convert any object or system into mathematical language via proportional description, this would shift the musical response from one scientific paradigm to another. If retranslation into quantities is rejected, the next approach when considering more systematic mappings might be to choose aspects of the scientific system to apply to musical parameters – a type of puppeteering, where one part of the musical whole for that moment is pulled by the string attached to its chosen referential anchor. The usefulness of this approach when considering a complex system becomes less intuitive, particularly when the number of musical parameters and their respective rules for use becomes so complex as to be acoustically illegible. The mechanism for, say, the transmission of a signal in human nervous system could be broken down into its component parts, and each of those could be described using musical parameters mapped to each (for example, I could see Xenakis approaching the change in electrical gradient in the neuronal cell membrane as a series of operations[11]). However, the attempt to describe the number of ions, channels, and the different conditions for the opening and closing of each could result in a musical system that falls victim to the accusation Xenakis

[11] There is also the example Varèse conceptual rendering of ionisation, which will be explored later.

levelled at linear polyphony in the article 'The Crisis of Serial Music'[12] that it 'destroys itself by its very complexity', due to his charge of a 'contradiction between the polyphonic linear system and the heard result' (Xenakis, 1992, p. 8).

If all such fundamentalist approaches to 'translation' of parameters are rejected, it raises the question of how or why music could be said to be informed by a scientific process or idea. If the music does not conform to the same consistent identification of quantifiable elements for its own sake, it necessarily estranges itself from the discipline it is deriving influence form since science is a system verified by reproducibility of evidence-based metrics. Yet, even in the most systemised approaches taken by composers, where parameters have been mapped very carefully, these choices still appear to have been guided by other, less explicit forces. In *Formalized Music*, Xenakis is careful to describe the basis and function of glissando vectors in his work. As to why he chose the glissando, he explains it 'can be assimilated *sensorially* and physically into the mathematical concept of speed' [emphasis added] (1992, p. 13). In a discussion of Varèse's *Density 21.5* (1946) Candace Brower asserts, 'for it is not the physical forces themselves that we map onto music, but rather our embodied experience of them…External forces give rise to internal ones, not just of the body, but of the mind' (1997, p. 40). On a spectrum of composers discussing musical responses to forces in their work, Xenakis is certainly on the more formalised rather than intuitive end, but even that degree of organisation in music does not preclude joint consideration of sensorial and (perhaps) personal synaesthetic relationships and embodied experience both in the choice of musical parameters and their specific use. These relationships can also be present without the conscious knowledge of the composer, since as Brower also points out, 'some dimensions of the musical mapping are carried out at such a visceral level that we may not be conscious of their metaphorical nature' (Brower, 1997, p. 37).

[12] As quoted in Xenakis (1992).

An embodied perception of physical properties could explain why two composers sometimes arrive at the same solution when describing properties of the physical world in music, such as sensations and ideas of 'curved' space in music. Xenakis was not the only composer to seek a way to represent this shape within the limited scope of the instruments he was provided. Years before, Varèse encountered the same limitation – 'for instance, I have always felt the need of a kind of continuous flowing curve that instruments could not give me. That is why I used sirens in several of my works' (Varèse & Wen-chung, 1966, p. 18). That a glissando should represent a curve seems intuitive, although why this should be the case is harder to identify. The gradual increase in oscillatory speed between two fixed frequencies is not 'curved'. Even when taking the cyclic nature of waves into account, a movement between pitches is simply a change in dimension of the circle (if viewing the wave viewed end-on). When written on the page, a glissando is typically a straight line, suggesting it is not the visual aspect of written musical language behind the association. Perhaps the doppler effect is what is behind a sensation of movement,[13] but this phenomenon still does not account for any notion of *curved* movement. Whatever the reason for the link, the ability to *feel* the association between smooth changes in pitch and the principle of a 'curve' and agree to its efficacy as a musical allusion does not appear to depend on the ability to explain why that might be so. It is precisely this type of intuitive, embodied, obscured and metaphorical association that I found myself most drawn to in many of the works of the portfolio.

This 'metaphorical mapping' or as I sometimes describe it 'thinking through music'[14] felt not only to be a more appropriate approach, but also more interesting way of exploring areas of science involving intricate systems that are best understood through exploration of their process-based mechanisms or formal arrangements rather than their quantifiable

[13] The engine sound of a vehicle moving from behind to in front of a pedestrian might sound akin to a glissando in its perceived overall rising and falling pitch motion.

[14] Or as Xenakis describes it 'we can reason by pinning down our thoughts by means of sound' (1992).

relationships.[15] Since it is perhaps 'more accurate to highlight the impossible conceptualisation of music as an autonomous domain that is fully detached from other conceptual frames that human beings mentally develop' (Besada, 2019, p. 263), a frame that can be obscure, as Brower (1997) points out:

> 'It is also important to remember that when we map structure from the physical world, we adapt its features to those of the musical domain, some aspects of which - like the cyclic structure of pitch space - have no direct counterpart in the physical world. For melodic forces to be experienced at all requires a leap of the metaphorical imagination. Even though the constraints imposed by the structures of the physical world and those of the human body promise a fairly high level of intersubjective agreement, the products of such imaginative leaps may vary from one listener-or even one listening-to the next.' (p. 41)

Since this phenomenon can have complex and unstable causes, and can change been score, performance and listening, following these implicit associations and reflecting on their creative manifestations seemed a useful and potentially rewarding focus of this artistic research.

Ligeti's explanation of his ideas on *Lontano* (1967) reflects this woolly space between metaphor and meaning. Ligeti remarked: 'I rather imagined a vast space of sound in gradual transformation, not through dense chromaticism but through a constantly changing pattern of color like a moiré fabric' (Ligeti cited by Bauer, 2004, p.141). These comments demonstrate a more personal, intuitive mapping process between music and the extra-musical ideas he was engaging with, one that better describes his work with mathematical concepts than a view that expects a more 'scientific' (systematic or organised) method – an assumption often encountered in literature that attempts to locate the science in his work. Ligeti may have described his compositional practice with a 'closeness' in respect to 'geometric thinking

[15] In my own practice I found that, not only does this avoid the problem of the mapping of parameters becoming too unwieldly, but it also produces new ways of approaching creative decisions that include many more aspects of music-making other than musical parameters themselves such as rhythm, pitch, timbre etc. (e.g., conceptual interplay between performer interaction, theatrical elements, additional media, interrelation between works etc.)

manners', and stated that fractals inspired the fourth movement of his Piano Concerto (1985–1988), but no 'fractals' have been found within either the sketches or the final work (Besada, 2019 p.262).

A similar use of indirect conceptual mapping could be viewed in Varèse's *Ionisation* (1931), which according to analysis by Jean-Charles François provides the 'idea of superimposing timbral identities in different densities' that were like a 'a gathering of multiple voices which talk together but do not really listen to each other' and these individual objects are 'welded into an abstract form that will completely transform their appearances' (1991, p. 62). This, the author argues, could be the 'ions' that 'come to us in a given state that cannot be modified, but the process of "ionisation" is precisely to transform them, nevertheless, into something more than they were at the beginning' (p.61). The idea of change by an additive process could have been arrived at by purely compositional thought, however while no 'ionisation' could be identified within the score without applying a particular metaphorical lens, the work again demonstrates that we need not rely on overtly literal systems of translation, retranslation, or direct mapping for there to be meaningful compositional responses to extra-musical ideas.

Mapping can be achieved through a variety of compositional strategies, and exhibit greater or lesser degrees of organisation, as has been explored in the literature. McLaughlin (2011) refers to Tristan Murail's *Attracteurs E´tranges* (1992) as a work that resembles poetic mimesis in describing 'warped trajectories', and Rolf Wallin's *Onda di Ghiaccio* (1989) as a dynamical system explored through sonification, a more 'rigorous approach to translation, where the equation or resulting data is mapped – directly or indirectly – onto some parameters of sound' (p.129). The selection of works outlines a potential scale, or typology of responses to dynamical systems in music. This topic is particularly interesting to investigate for a potential sliding-scale given that musical works and installations can get closer to a working model of a dynamical system than is possible for other mathematical or scientific concepts, something that McLaughlin explores in *There are Neither Wholes Nor Parts* (2011) whre the comopser uses 'feedback and hysteresis to generate musical structures in realtime through the interaction of two elements' (p.133).

Considering the works in this portfolio with respect to the types raised by McLauchlin, they would predominantly fall under 'poetic mimesis'. This is partly because the scientific theories and practices explored in the research did not lend themselves to literal models in music, as certain other, predominantly mathematical concepts can (the aforementioned dynamical systems being one). Another reason (for why I was drawn to this type of metaphorical analogy) was discovered during the early phase of the research. I had been composing with a similar idea of a spectrum in mind: from what I determined at the time to be 'abstract' (synonymous with McLaughlin's 'poetic') to 'concrete' (the last available point on a scale of organised translation since it could not achieve a 'literal' status, and sonification was similarly unavailable due to the nature of the extra-musical ideas). Having written works up to the 'concrete' stage,[16] where a total system of parameter-mapping conformed to a set rule-structure to create the work, I realised I had no interest in composing further works in this manner (despite enjoying the result). Consequently, the idea of a spectrum became less important to the methodology of the research, and instead of continuing to pursue ways to relate the music more directly to the science, I allowed each collaboration and concept together to inform the choice of compositional direction.

vii. Collaboration

'In a musical culture that has understood the performer's role primarily as mediator between composer/piece and audience, very little attention has been paid to the performer's potentially significant mediation between composer and piece' (Fitch & Heyde, 2007, p. 72).

The last two decades have seen a surge of new research in the field of collaboration in music, particularly between performers and composers. Of most influence on this research project were Fitch and Heyde (2007), Roe (2007), Roche (2011), and Kanga (2014), the edited editions of Clake and Doffman (2017) and Redhead and Glover (2018). Many of these have built from a

[16] The works from this early period are not included in the portfolio since they did not demonstrate the progress in voice or research findings that the later strategies achieved.

body of work by Georgina Born and Lydia Goehr on the roles of the performer, composer and the 'work-concept' within a western classical music tradition, as well as pianist Peter Hill's writing on the topic (1975, 1986 & 2002) and the influential text by Keith Sawyer and Stacy DeZutter from the perspective of improvised theatre, among others[17].

This body of literature, and its influence on many of those I have worked with over recent years, had increasing impact on the choices I made during the composition and workshop process. For example, the approach provided by Roche and others on working with performers on clarinet multiphonics, was of particular influence on the later works presented in the commentary (The *Aubergine Soup Tourine* series, including *Output VI* and *Sad Dog Eating*). These works were approached with a collaborative perspective in mind, beginning with discussions between myself and the clarinettists both on the terrain we wished to explore together, as well as the method for doing so. This was a large shift in thought that was brought about by the work of those in this area who have highlighted the importance of considering an instrument-performer pairing and demonstrated the benefit of working together with the performer to discover not only solutions, but possibilities. Whilst today that seems obvious, in my early studentship there was an instinct to assume that a diligent composer ought to form, or be working to form, a comprehensive mastery over the use of multiphonics in the same way they are expected to become experts in all other areas of performance technique. This cultural shift has enabled me to challenge head-on the unhelpful, patronising attitude that a 'good' composer arrives at a rehearsal knowing everything a performer does about their instrument's sonic possibilities, and the *best* composer arrives knowing more. Looking back to a time I felt that this was a true representation of the expectations of a composer, I can see that this view may have been given greater credence due to the anxieties of myself and others not to 'waste valuable rehearsal time' by not knowing in advance, at the very least, exactly which questions to ask the performer to elicit the one response that would successfully 'solve the problem' of the sonic matter at hand. The impact that this body of work has had on my practice goes

[17] Particularly Christopher Small's work on 'musicking' (1995 & 1998) and significant later contributions to the field by Clarke, Doffman & Lim (2013) and Alan Taylor (2016).

beyond individual matters of instrumental technique, or even approaches to working with performers. It is not an exaggeration to say that by engaging with the philosophy of approach to collaboration demonstrated in the literature above, my perspective on what my role is as a composer itself has fundamentally changed. The result of this is evident in the gradual progression over the research toward new work-creation strategies such as in *Output VI* (including its component works *Output IV* and *VIII*) and *Sad Dog Eating* which were developed over a series of workshops with the performers, with each experience informing the creation of the score for the next.

Scores such as *Output IV* and *Output VII* were also created with the social and accessible dimensions of music-making in mind, rather than just the acoustic result, or interesting compositional choices. The *Outputs* served a dual purpose, in that the type of scoring (text and graphic) was chosen to be useful afterward to groups that include non-expert or non-reading performers such as *Contemporary Music for All (CoMA)*.

viii. Collaborating with Scientists

Two collaborations with scientists took place within a wider programme facilitated by PRiSM . Both of these connections – with Dr Kirstie Andrews and Professor Mathias Brust respectively – were made initially through the 8^3 programme that aimed to pair scientists with composers, both of whom had an interest in working with one another. The programme was open in its aims, and with the exception of one expected outcome, which was the premiere of a new work at a concert for the event, no expectations were placed on the type or number of outcomes we wished to pursue. Between us, we decided that the purpose of the collaboration should be to enriching our practice in the broadest sense possible, rather than a pairing designed to produce a 'piece'. What this looked like to us was spending time talking without a specific aim in mind, sharing our research and methods, and engaging in iterative discussions of music as works were developed within this ongoing collaboration. This philosophy was also shared between the two groups of heath data scientists and myself for *Hub* and *Dawn, on the Morning After the Storm,* with the distinction that one musical work was created during these, rather

than a collection of works as was developed during the collaborations with Andrews and Brust (but was no more focused on this as 'the outcome').

This philosophy behind the collaborative partnerships explored is important to outline, as it assists in positioning this form of collaboration within a wider context. Whilst the growth of composer-performer collaborations has provided an increasingly wealthy domain from which to draw models, methods and meaning when working together, looking to the same body of work for assistance in framing collaborations between composer-scientist relationships creates problems. This is due to the emphasis many theoretical and practical models have on the direct musical input of the collaborator. Whilst a collaborative partnership, regardless of the non-musical nature of the input of the other party, at least moves away from the idea of the composer 'as a sovereign artist, creating music from their imagination alone', (Taylor, 2016, p. 3) a composer-scientist relationship such as the type engaged in this research would not satisfy a criteria such as Taylor's for true collaboration. The author's perspective highlights a danger in the over-use of the term 'collaboration' that can flattening all meaning. Taylor argues that 'many of the activities described as collaborative by writers would be better described as examples of one of the other forms of working together. In particular, many relationships are described as collaborative when they might be better described as co-operative or consultative' (p.569). The author suggests narrowing the use of the term to just the cases in which, rather than a composer only being influenced by their collaborator, or (when collaborating with performers) responding to their own knowledge with a certain performer in mind, there is 'more than one artist directly involved in the creative work' (p.566). Accepting Taylor's other terms however, moves the scientists into a type of service role, negating not only their part in the inventive realm (Fitch & Heyde, 2007), but also the impact of this work on their own practice.

Applying the same framework of a composer-performer collaboration to a composer-scientist relationship clearly doesn't fit, since unless the scientist becomes actively involved in the creation of the work or performance, there is no space to recognise their input as a collaborator. That is not to say that all working relationships between composers and scientists

are necessarily described as collaborative, some might be closer to the tool-acquisition style of working Fitch and Heyde (2007) describe between composers and performers.

> Collaboration is frequently a matter of the performer giving the composer access to his 'box of tricks', or of the composer presenting notated sketches to be tried out, adopted, discarded, or refined. Such pragmatic approaches may well be beneficial to both parties, but they come at the cost of reinforcing the boundaries inherent in their respective roles. (p.73)

In our work together, it has neither been mine nor the scientist's intentions to trouble any distinction between our roles as scientist or composer in the general sense (eg. I did not take on the duties of a scientist, and nor did they 'compose' the music), but rather to find a way of working together that moves beyond a one-sided exchange designed to extract knowledge from one domain for the purpose of appropriation into the new, and for the primary benefit of the contractor.

In each of the partnerships, our primary aim was to invite a type of cross-talk such that it was not only the science that was influencing the music (or the scientist the composer), but the other way around as well. Whilst this is harder to define, record and evidence (and outside of the remit of a composition commentary), all scientific collaborators in this research communicated a belief that this had indeed happened, citing evidence such as a move to publish a paper they wouldn't have otherwise (Andrews) and new insights into their work, including its impact, as a result of spending large amounts of time explaining their current challenges to a non-scientist (Brust and Semple).

To find definitions and types of collaboration that did recognise our work as such, the scope needed to be widened out again to research that considered collaboration in a broader sense. There are many models of collaboration in artistic literature, some of which have been imported from general settings, such as Montiel-Overall (2005b), others which have been created or adapted toward a musical setting, such as Vera John-Steiner (2000) and Hayden and Windsor (2007) which still leave room for different forms of creativity to be represented. In the John-Steiner model, a collaboration with a scientist could fall under 'complimentary collaboration', based on discipline-specific knowledge, clear roles and division of labour, and

where the shared experience created by the complimentary expertise can work to 'sustain the partners' creative endeavours' (John-Steiner, 2000, p. 198). Using the Hayden and Windsor, such collaborations could be described as interactive, given that there was a direct negotiation with scientists in the writing phase of the work, where the composer is still the agent determining the presentation of ideas in the final work. Whilst none of these provide an exact fit (especially when considering the ambitious philosophy of bi-directional exchange against the practical discipline difference), there is justification in the use of the term collaboration, even when it doesn't look like the types of collaboration a composer might typically engage with.

Indeed, that the knowledge and skillset is so far out of the realm of arts partnerships is precisely the reason it has been inviting to explore. There is the idea that new tools might become available, new mindsets and methods, but perhaps most of all, the unexpectedness of what might come up in the dialog. As first identified by Roche when describing trust as an important part of a collaboration (p,132), the author of Building Trust in Business, Politics, Relationships and Life makes the case for collaborations in discovering what 'we Do Not Even Know That We Do Not Know.' I would add that Solomon's next point is particularly relevant to the case of composer-scientist collaborations, 'This is not a realm that most of us can enter alone. We can arrive there only with and through other people' (Solomon & Flores, 2003, p. 50), since the sentiment is particularly relevant to domains of knowledge with little overlap. I might be able to transfer some of my skills to learning the clarinet in order to acquire some of that domain-specific understanding (although not that of a dedicated expert), but I must rely on a scientist for understanding of their field, or commit myself to a significant amount of time gaining all the fundamental knowledge required to achieve even the most basic understanding in that domain. By putting that time instead to working with someone already in possession of that understanding, not only can new information become available, but a different perspective as well. In itself, creates something new:

> By the very nature of having two unique creative beings in a room together, it has to create *something* that neither could have discovered alone. The very presence of a collaborator alters the space of the room; the creative mind frame of each individual shifts, and something new is created. (Roche, 2011, p. 96)

To conclude, collaborations between the scientists and myself in this research have navigated a different set of boundaries, roles, and affordances than the performer-composer collaborations, but the impact should be considered in equal terms. Not only do the collaborations demonstrate value via the creation of individual works, and impact on our wider practices, but also in the potential for future exploration across the borders between the arts and sciences.

CHAPTER 3

PRACTICE REVIEW

ix. Composers & Science: Introduction

The first two chapters have outlined both the definition of science in this research, and the methods used in the portfolio to explore these ideas. This chapter discusses a criteria for *works informed by science* so that a contextualisation of this practice within the wider field can be explored.

x. What is music informed by science?

In 'Experimental Music Since 1970' author Jennie Gottschalk collects the works discussed in Chapter 2 under the title 'Scientific Approaches'. Since this term is not defined, it is left to the reader to infer Gottschalk's understanding of what constitutes a 'scientific approach' in music by the works described in the sub-groupings.[21] A clue to the author's position is given following the discussion of a body of Martin Arnold and Lawrence Crane's work:[22] 'The apparent simplicity of musical materials only initially obscures the fact that there is discipline and research here, and genuine discovery within these familiar musical confines' (pp.43-44). But what differentiates a non-scientific approach that, through a different mode of artistic research similarly generates 'genuine discovery'? What does 'discipline' mean to an artist?[23]

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[21] These are: 'acts of discovery', 'harmonic relations', 'playing with numbers, 'learning by making' and 'finding hidden sounds'.

[22] Works mentioned in this example are Crane's *20th Century Music* (1999), *Movement for 10 Musicians* (2003) & *See Our Lake* (1999) along with Arnold's works on the Bozzini Quartet's *Aberrare* Portrait CD.

[23] If a composer writes a piece high degree of indeterminacy based on e.g., multiverse theory, what measure is applied to define how disciplined this work/composer was? Time on task? The systematic attribution of parameters to extra-musical information? The complexity of the interactions between

Would Crane or Arnold agree with the description of their approaches as 'scientific'? (And what would it mean if they didn't?) It is easy to find mention of artistic modes of inquiry and discovery, they are common terms in artistic discussion so it appears many artists identify with them. However, existing literature often produces varied (and sometimes contradictory) examples when describing works each author deems to possess a 'scientific' aspect or character.

This difference in received or constructed meaning of 'scientific' approaches to music is not limited to artists. Returning to Ligeit's friend Peitgen, the mathematician describes *Poème symphonique for 100 metronomes* (1962) and *Continuum* for harpsichord (1968) as having an 'experimental and scientific character' (Peitgen, 2011, p. 91). Yet as the mathematician himself acknowledges in the same paragraph, at the time of composition of these works, Ligeti 'had in mind numerous superimposed grids, moiré patterns, which would result in changing rhythmic structure' (A topic shared with *Lontano* as mentioned previously). The optical illusion that caught Ligeti's interest had attributes shared with science, namely they both (sometimes) used grids. But if using tools and parameters shared with some sciences qualifies a musical work as scientific, then most western art music is 'scientific music', since it deals in quantifiable notated parameters and relationships between resultant acoustic frequencies[24]. Whilst is it is difficult to determine whether Ligeti's exploration of optical illusions was jointly driven by a confirmed interest in science elsewhere in his body of work, it is certainly true that the composer did

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performers? It seems that 'discipline' is not assisting the task in identifying what constitutes 'scientific' approaches.

[24] The potential quantifiability of many aspects of western art music (both in symbolic notation and heard result) itself presents challenges to those looking to uncover, or ascribe notions of 'maths' to historical works, a problem compounded by the shared early history of the two disciplines. In a discussion on contrapuntal works, harmony and figured bass, Locanto asserts 'Notwithstanding the fact that the type of mathematics involved in these areas of musical composition and performance is very basic – a simple arithmetic – the fact remains that techniques of traditional harmony and counterpoint were based on numerical criteria only to the extent that basic music theory had traditionally reduced the most fundamental elements of music grammar (pitches, intervals, durations) to numbers. Theory was indeed the very ground on which mathematics and music had always met in Western culture' (2019, p.xiii).

relate *some* of his works to an interest in mathematical ideas (Ligeti, 1988). This presents an opportunity to create a distinction between works that can be comfortably identified as 'music informed by science', and those that cannot – whether by clear disqualification or insufficient evidence.

The definition supported by this commentary as 'music informed by science' is neatly differentiated by an anecdote supplied by Petigen (2011), when discussing Ligeti's more direct engagements with science, following a conversation with Steve Reich:

> 'I recently had the chance to discuss this ['perceptual elements' experienced by Peitgen upon hearing Reich's *Piano Phase* (1967)] with Steve Reich and was surprised to hear that he was not aware that his music had any connection to current brain research. In fact, this aspect did not really interest him. And this even though *Piano Phase* and *Come Out* (1966) could be interpreted as perceptual experiments. In the case of Ligeti, the relationship between composition and effect was virtually reversed. He followed the advancement of brain research with great interest and extraordinary insight, and there is no doubt that his enthusiasm for current scientific advances was the unifying inspiration behind his creative work.' (p. 93)

It is therefore not the relation of sound organisation to a general systematic process, presence of scientific attributes such as shared language,[25] tools, or ability of others to find 'real science' within a work that I purport to be *music informed by science* here, rather, I propose a definition with similar considerations to that of Dahlhaus' *programme music* explored in chapter 2. The qualifying attributes being: A compositional process that is informed by the consideration of an aspect of science (including its theoretical and physical products as well as its methods); that it is part of the work-object (such as mention within a programme note or verbal description); as identified by the composer. As such, in the example above, the fourth movement of Ligeti's Piano Concerto (1985–1988) is included, since a reference to the

[25] For example, do all of the composers in the 'playing with number' section of Gottschalk's consider their pieces 'scientific' due to the inherent mathematical properties of number? Or were they drawn to number for the ability to introduce aleatoric elements to their process?

mathematical system was acknowledged by the composer, whereas work prior to his known interest in dynamical systems (that may well share musical similarities later used for this purpose) are not. Therefore, I will focus on composers whose work may not seem as overtly 'scientific' to a listener (whatever that may mean to a given individual), but who have given specific acknowledgement of a scientific influence in the process of developing their work/s.

xi. PRACTICE REVIEW – Composers and Science

The increasing number of composers dealing with scientific ideas…for nurturing their creative practices is a fact, whether we like it or not (Besada, 2019, p. 261).

From early in my compositional practice, I was drawn to strategies that I felt paralleled some aspect of scientific concepts. I looked for other composers who did so, in a conscious an attempt to understand my own apparent need to express through music that which I was learning about scientific concepts.[26] Through investigation into the work of Xenakis, Ligeti and Messiaen in particular, I developed an understanding of the potential for the type of conceptual mapping (introduced in Chapter 2) in producing specific compositional decisions and the development of internal logic in a post-tonal system, as well as the musically distinctive pathways and methodologies that can result from individualised approaches to this.[27]

The validity of this type of extra-musical influence was apparent from the legacy of the works produced by each of these composers in this area. The breaking of compositional ground for Xenakis in the use of ruled parabolic lines in *Metastaseis* (1953-54) is one such example, as is the enduring appeal of Ligeti's *Piano Etudes* (1985-2001) and influence of Messiaen's

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[26] For instance, a lifelong interest in astronomy that drew me to exploring the Laplace resonance cycle of three moons of Jupiter, which I related to a cycle of pieces that referenced each other at specific intervals, as if the pieces were orbiting one another resulting in musical conjunctions.

[27] Messiaen, Ligeti and Xenakis have all explored mathematical concepts, in ways that have resulted in the further development of their distinctive compositional voices.

ornithological expeditions in *Réveil des Oiseaux* (1953) and *Catalogue d'Oiseaux* (1956-58) as well as mathematical excursions across his career. But more important than impact, from my perspective, was the use of these extra-musical interests to relate meaning and a sense of logic to compositional decisions made in each individual work, as well whole bodies of work such as those relating to the works above by Messiaen and Ligeti in particular.

Recent years have seen a groundswell of engagement with the ideas of science within the arts. This has resulted in the development of new incentives such the Minerva Scientifica project (Minerva Scientifica, n.d.) and the founding of centres such as the Royal Northern College of Music's Centre for Practice & Research in Science & Arts (PRiSM) (PRiSM, n.d.) . Awarded a major grant that enabled the formal opening in 2019, PRiSM had been establishing its methodology concurrent with this research and created opportunities for composers and scientists to meet, resulting in my collaborations with Dr. Andrews and Professor Brust as previously mentioned.

PRiSM was founded by Director Emily Howard (also this project's secondary supervisor) following from her own compositional interest in drawing from scientific phenomena. *Magnetite* (2007) is an orchestral work where musical material is shaped by the composer's response to the structure and physical properties of magnetite crystals. 'I like to think of Magnetite as a journey deep inside one of these crystals. Musical material behaves as though it is being attracted and/or repelled by magnets. Melodies take the paths of particles in a giant crystal lattice' (Howard, 2021). This framing of a scientific idea through musical language is also apparent in the composer's later series *Orchestral Geometries* (2019). On its development, Howard describes how the mathematical shape provided an imaginative cornerstone. 'Each work is titled with the shape in question and it's as though this shape was a filter through which myriad decisions about the piece were made. These rational decisions affect the proportions of the work and its soundworld' (Howard, 2020).

First launched during British Science Week in 2018, PRiSM developed a series entitled 8^3, which pairs 8 composers with 8 scientists and 8 performers, culminating in a concert featuring resultant works. These collaborations have introduced new composers to the idea of creating

works informed by science, and as well as providing ways for scientists and composers to meet, with some leading to longer-term collaborations, such as the one between myself and Dr Andrews discussed in this commentary. The composer-scientist collaborations have deployed a range of aims and strategies, some which demonstrate the possibility of additional outcomes, such as the ability to act as awareness-raising mediums as in Steven Bradshaw (composer) and Dr Graeme Heyes' (scientist) *dBA (LOUD)* (2018), informed by how 'airport noise can cause significant impacts to the quality of life of airport communities'.[37] Other partnerships sought ways to combine their practices, such as Jingyu Chen (composer) and Dr Robyn Grant's (scientist) project exploring how sea lions move to different rhythmic impulses provided by Chen, research that was then used to inform an audio-visual work[38]. The 2020 8^3 series occurred during lockdown, and as a result the works were recorded and premiered online by Riot Ensemble. The works include *Spin Excitations* by Shruthi Rajasekar (composer) in collaboration with Dr Lucy Clark (scientist). Rajasekar describes her work as 'a musical modelling of magnetic moments at the quantum level', and explores a balance between 'regularity and chaos' and the idea of giving way 'to the 'humbling concept of emergence: the possibility of small and simple components coalescing into a synergetic, complex, and unexpected creation.' [39]

The Minerva Scientifica music-theatre and research project pairs women scientists with women composers, as well as commissioning composers to write about the work or lives of women scientists in history[40]. Created by Electric Voice Theatre and running since 2013, the initiative has received support from Arts Council England, and resulted in numerous collaborations, works, and outreach projects. The podcast series produced during the 2020

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[37] (Bradshaw & Heyes, 2018)

[38] Chen, J. & Grant, R. (2018).

[39] (Clark & Rajasekar, 2018)

[40] such as *The Franklin Effect* on the work of DNA Scientist Rosalind Franklin that paired four scientists at Kings College London with composers Cheryl Frances-Hoad, Lynne Plowman, Dr. Shirley J. Thompson and Kate Whitley (Electric Voice Theatre, n.d.-a).

lockdowns offers an in-depth look into the work of participating artists and scientist (Electric Voice Theatre, n.d.-b). Frances M. Lynch provides an insight into how some of the scientific ideas explored during a collaboration with Ann-Marie Weijmans were developed into the work *Dark Matters*:

> Weijmans work on galaxy formation includes the intriguing question – Does Dark Matter Exist? …The music is built from the name of the galaxy Dr. Weijmans first researched – NGC 2974 – which provides all of the notes for the instruments in the first section. (N = B then we have G & C and then the numbers refer to notes from the major scale of C). The Second Section – FIGURE 17 – refers to a graph from one of her first papers which shows the dark matter curve in relation to the movement of stars and gases. You will hear the short sharp brass interruptions which show where the observations on the curves were made – looking for where stars should be! All the notes in this section are created from the names of the 2 featured astronomers (Weijmans and Somerville) – using the letters as a code for notes in a specific – though unconventional – musical scale. Dark Matter is at work here – forcing the notes into time and pitch places they shouldn't have gone! (Lynch, n.d.)

When considering the works of individual composers, rather than the centres and projects describing themselves providing collaborative opportunities or otherwise identifying a link to science, the issue as to whether it's appropriate to categorise works as responding to science again arises. It is not unusual for composers to give titles to works that imply a definite subject matter that were not in mind during all, or any, of the writing process (Penderecki's *Threnody to the Victims of Hiroshima* being one well-known example (Schloesser, 2014, p. 514)). It could be argued that a title that gives the impression of a science-based influence could be *experienced* as such by a listener, but it's the construction of the work with regard to matters of science that is the conditional factor here.

One reason I suspect there has not been as much musicological attention paid to this topic as the more systemised responses to science is that core analysis may not be very helpful in identifying or illustrating abstract types metaphorical mapping or poetic mimesis. These may need additional support via an account by the composer that sufficiently probes how responses to the science and to the music were related. For that reason, instances where

composers have given accounts of such relationships are given the most weight in this review, however nebulous they can sometimes be. For example, Missy Mazzoli's *Sinfonia for Orbiting Spheres (2014)* is described in the programme note as 'music in the shape of a solar system, a collection of rococo loops that twist around each other within a larger orbit,' where title and description also refers to the linguistic connections to the hurdy-gurdy, and is 'a piece that churns and roils, that inches close to the listener only to leap away at breakneck speed, in the process transforming the ensemble turns into a makeshift hurdy-gurdy, flung recklessly into space' (Mazzoli, n.d.). This description sufficiently demonstrates a thought process that relates the concept of orbiting bodies to musical representations, and also highlights the second problem that can arise when attempting to give specific examples in the works of other composer who may be informed by science: there are often interrelated metaphors at work, and only Mazzoli (if anyone) could point to a bar in the score and explain its relationship to either one or both of those extra-musical influences.

Composers who use metaphorical mapping between domains sometimes draw from a number of influences, and since this can be true not just for a single work but across a practice, discussing not just 'compositions informed by science', but '*composers* informed by science' becomes even tricker territory. This is pointed out not because it's an aim of this practice review, but because via inclusion in one, it could be argued that such a determination has been made. It is for this reason that the criteria used, as modelled from the Dahlhaus, places such emphasis on the presence of information pertaining to the work-object, such as publicly-given detail provided by composers, in the form of programme notes as well as interviews.

One composer with a number of works referencing scientific topics is Irish artist Ann Cleare. Some of Cleare's works demonstrate direct influence from an apparent interest in astronomy, such as *93 milion miles away (2016)*, a reference to the distance between the Earth and the sun that 'acts as a metaphor for two blocks of material that I juxtapose, two distant places. These distant places become like inverted realities, each driven by a search for suspension', (Cleare, n.d.-a) and *Eyam IV (Pluto's Farthest Moons) (2014)*, which intriguingly could have become one of those rare instances where the music and the science have a concrete relationship since the composer 'spent weeks suggesting names to the SETI (Search

for Extraterrestrial Intelligence) for Pluto's newly discovered moons.' Although the effort ultimately proved unsuccessful, the composer reflected that 'thinking of names for Pluto's moons provided all sorts of inspiration for eyam iv, and how the spatialised ensemble interact with the solo contrabass flute' (Cleare, n.d.-b).

As with Mazzoli, Cleare combines interest in scientific knowledge with other artistic catalysts such as written texts, such as in *teeth of light, tongue of waves* (2017-18):

> The piece reflects Cleare's interest in paleoceanography, the study of the history of oceans in different geologic eras. This has environmental connotations, as do the Irish texts incorporated into the piece. One selection about the seas is from ancient bardic poetry and another is prose from an article by the contemporary writer Doireann Ní Ghríófa. (Carey, 2022, p. 9)

Some of Cleare's other works exploring scientific concepts include *Ore* (2016)*, the physics of fog, swirling* (2018/19) and *on magnetic fields* (2011-2012).

Moving beyond composers for whom a personal interest in scientific topics seems clear, there are works that touch upon the important scientific topics of our time, such as knowledge that has emerged from climate science. It is more difficult in these cases to separate a response to the science *per se*, given the backdrop of information and discussion on the topic scientists and non-scientists alike are exposed to. Regardless of driving factors, there have been a number of responses to this topic that are certainly driven by climate science, if not caused by our overuse of the technologies science has afforded us. Laura Bowler, Tansy Davies, Hayley Suviste are composers who have each responded to this topic in its various forms in their works. Bowler's *Houses Slide* (2021) used alternative sources of energy to power the house and stage lights as a direct response by the composer to the climate emergency, and the work's movements explore the range of human experiences as a result of this situation as sourced by the composer (Interlude, 2021). Davies' *Cave* tackles environmental issues head on by telling 'a story of human suffering balanced by the healing force of the natural world. The central character is a man fleeing from the devastating effects of climate change, on a quest for his lost child' (London Sinfonietta, n.d.). Whilst Suviste's *Unfrozen Neva* (2020) considers 'the transition we're going through with our world, documenting the impact of global worming on

the usually frozen solid, but now free-flowing River Neva in St. Petersburg' (Huddersfield Contemporary Music Festival, n.d.).

As mentioned, works in this thesis do not engage in any form of sonification. It is still worth noting that many composers working with science have used data in their work in ways that are often referred to with this term (even when other terms might be more appropriate, such as 'data-driven music' (Scaletti, 2016), or the recently proposed 'musificiation' (Bonet Filella, 2019) among others). There are many artistic decisions that can be made between the data as received by the composer and work as received by an audience. This complexity has been with us since Lucier's *Music for Solo Performer*, a work that itself challenges the title of sonification even as understood in the artistic and not scientific sense, despite its impact on the development of the field of musical sonification, and its oft-cited position as one of the first works in this genre (Straebel & Thoben, 2014). Composers such as Annea Lockwood (*Dusk* (2012)), as well as the previously cited Carla Scaletti (including *h–>gg* (2017) and the score for Gilles Jobin's *Quantum* (2013)) and Bonet Filella frequently explore data in their musical practice, with the latter two also providing insightful academic writing on the topic.

Staying on the topic of brain waves, Neuroscientist David Sulzer created *Reading Stephen Colbert'* with the help of Columbia Computer Music Centre Director Brad Garton, a work that bridges sonification practices with what might be better understood as a form of technological augmentation. In a setup that invites comparisons to the Lucier, the scientist wore electrodes to monitor his brain waves. In Suzer's work however, the signal was 'fed into a computer program created by Garton, which transformed them into musical notes' (Piore, 2012). The additional translatory steps engineered by Garton move this work further away from an idea of pure cause and effect than the Lucier, since Garton did not perform sound engineering modifications to the signal but wholly retranslated it into a different medium by an additional rule system. In this way, works such as this one not necessarily sonifying data so much as using it as a source for further composition or performance process.

With the increase in the affordability of home medical devices, composers have begun to incorporate devices that capture biometric information from performers into their works. One

such example is Ed Cooper's *…grown up, you are grown, and feeling stronger, feeling…* (2020-22)) that uses a heart monitor attached to the performer to determine aspects of the work. As with the previous example, the use of such devices might be more closely related to the idea of instrumental augmentation than sonification or science-informed works. A work that similarly uses speed differences to inform the performances is *Neuroknitting Beethoven* (2020) by artist duo Varvara Guljajeva and Mar Canet. Once again exploring applications of brain waves in performance, the collected signals 'affect Circular Knitic's (our circular knitting machine) pattern and knitting speed. The first one is composed of the peaks of attention level, and the second corresponds to the meditation state. In other words, the higher is the attention, the more dense is the pattern. And higher is the meditation level, the faster knits the machine' (Canet, M & Guljajeva, V. n.d.).

The works mentioned here provide only a sample some of the ways that composers and artists have been responding to science, natural phenomena, or the technologies afforded by recent developments or increased access in their work. This field is a dynamic and ever-evolving landscape. Regardless of compositional approach, the possibilities of interaction between the systems and languages are as endless as there are discoveries in science yet to be realised.

CHAPTER 4

RESPONDING TO SCIENCE: Degrees, Types & Opacities

In this chapter I will discuss works that were informed by different aspects of science (topic matter or process) and to different degrees (direct or indirect). *Monolithos* is presented as a work that is direct in its relationship to the scientific idea, both in its programme note and in the number and type of compositional decisions related to the scientific theory. For instance, the form and content of the piece were both constructed through conscious interplay between the functional aspects of the compositional process and the details of the scientific theory. On the opposite end of this spectrum is *His Black Box*, which was written with two frames of composition in mind: the response to the poem itself, and the theories of spacetime I found myself associating with it. Despite both frames informing the composition of the piece, latter is not referenced in the programme note. Since there was no systemic mapping of compositional parameters to the theory, this aspect is unlikely to be identifiable through analysis. A third piece, *A Length of String,* provides an example of another topic of the Portfolio – the exploration of combined acoustic potentials within an ensemble of related instruments. Lastly, *Mark I* is mentioned as an example of the scientific process as a topic of compositional interest. The relationships that each piece have to the scientific and other extra-musical influences are described below.

DIRECT

xii. Monolithos

This piece explores the 'big rip' theory of infinite expansion of the universe through two forms of musical movement away from a given centre. The first section employs chromatic augmentation from C natural moving outward in both pitch directions, the second section applies mirror harmony with the symmetrical C double-harmonic major scale in contrary motion

away from the tonic. The use of clock and alarm-like sounds are meant to express the existential dread brought about by considering the eventual distance between all matter in the universe this model predicts.

This work follows from a tradition of a compositional approach where structure and internal logic is chosen in response to an extra-musical influence.[41] The piece begins with the primary pitch from which all future growth in the piece emanates: C♮. Throughout, octave unisons are treated as the same note, but the first presentation of C in the lower register is significant, in that it acts as the first fundamental, from which all (other) octaves are derived.

A C diatonic cluster with an added G♭ [C,D,E,F,G♭,G,A,B] swells from piano to fortissimo, as an incomplete foreshadowing of the events (of expansion) to come. The pitches were chosen for the symmetry in the intervals when taken from the mid-point of F/G♭ (see fig.4.1).

[C		D		E		F		G♭		G		A		B]
	[T		T		ST		ST		ST		T		T]	

Fig. 4.1 – Intervallic spacing in opening cluster – Monolithos (bars 1-3).

[41] Such as in Ligeti's description of his *Piano Etudes* and fourth movement of his *Piano Concerto* having reference to dynamical systems (Peitgen, 2011, pp. 87–104), Varèse' *Ionisation* to the title subject (François, 1991), or Xenakis' constructions in *Nomos Alpha* (1965) & *Herma* (1961) described by the composer as 'symbolic music' which he describes as reasoning by way of mapping graphic symbols to sonic ones (Xenakis, 1992).

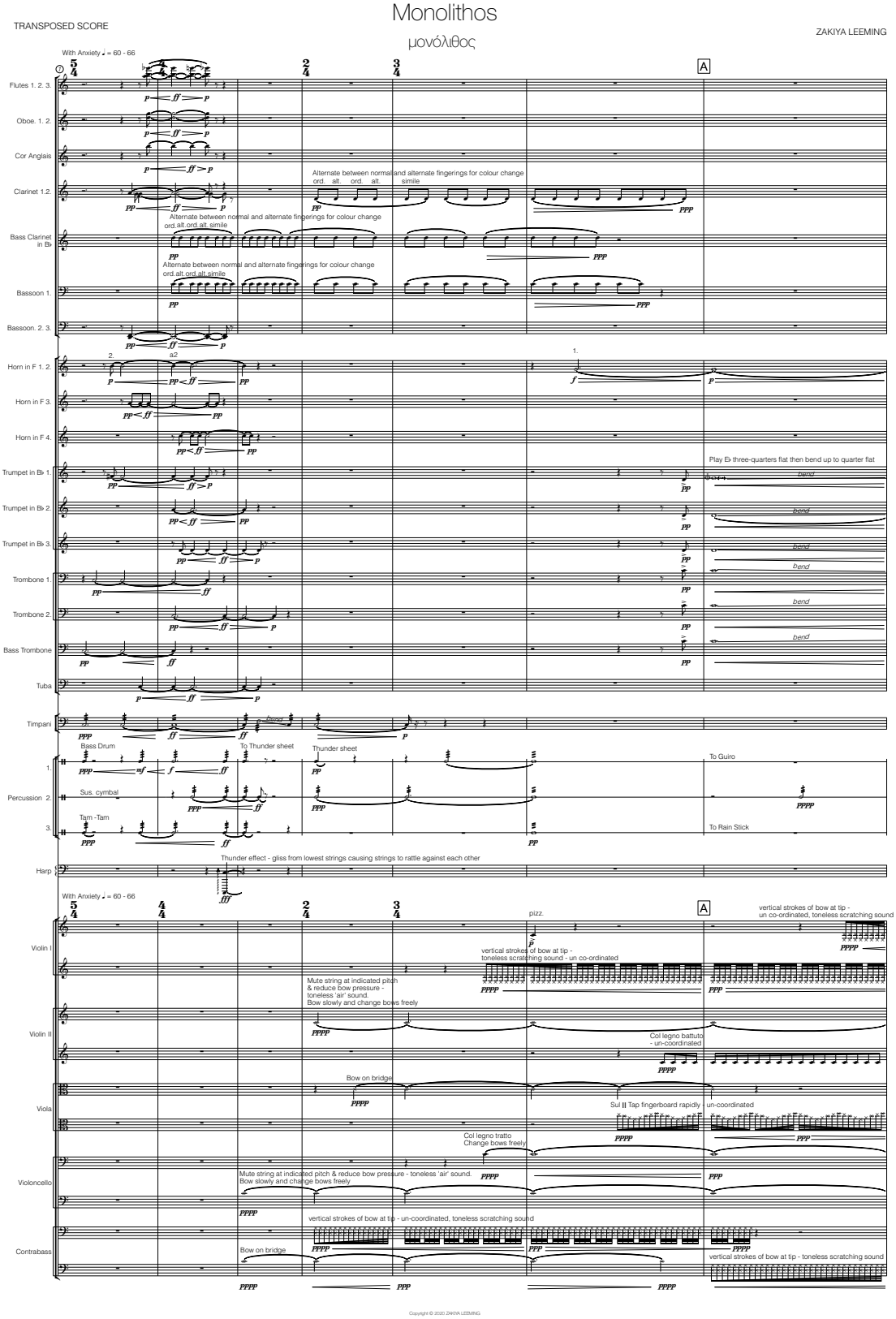

Fig. 4.2 – *Monolithos*, score (bars 1-7 – transposed score).

Following the introductory statement (see fig. 4.2), the piece is arranged in A/B format. Both sections describe the subject (expansion) using different pitch organisation systems. In the A section, the strings begin with indefinite and non-pitched material. The next pitch that is heard is the 'C' that represents the foundational pitch (the reason for choosing this pitch will be discussed in when addressing section B). The first movement in pitch by the brass travels only in microtones, returning to C by end of the note (bars 7-9 – see Fig. 4.3). Complete migration from C occurs chromatically in both directions in bar 10. The pitches C♯ and B are now available for the duration of this section. The A section progresses in this manner, with the greatest movement in pitch from the baseline C occurring in the upper winds and lower brass. Most instruments within the central range of the ensemble (lower woodwind & upper brass) hover around the median pitches (C as the centre of an A-E♭ axis). The same is mirrored within the string ensemble, with the violas at the median line.

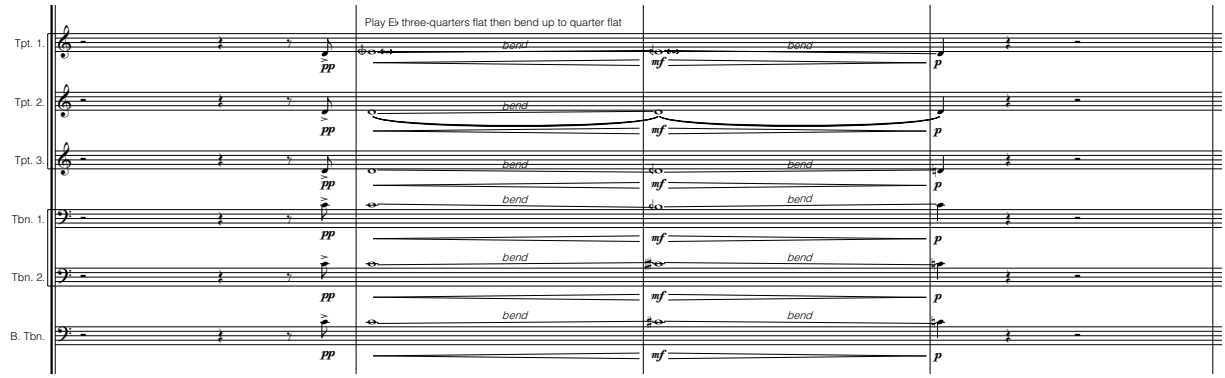

Fig. 4.3 – *Monolithos*, brass (bars 6-11 – transposed score).

Following section A, there is an interlude intended to suggest the passage of time using regular, dry percussive strikes on the wood block and snare (bars 59-62) that allude to clock-type sounds. The end of the A section marks the final expansion to include all chromatic pitches in the octave's aggregate pitches, now available in all registers. Section B arrives in a sudden, initial explosion of rhythm movement and freer movement of pitch. It also marks the introduction of some more expressive elements of the piece, composed with the perspective of a 'tone-poem' as it sets a programmatic narrative.

The pitch content in this section is derived from C double-harmonic major, and stepwise movement upward through the chords of the scale is mirrored by stepwise movement downward. This is initially seen as upward movement in the winds and downward movement in the strings and brass, later shared between the winds and brass in staggered and sometimes overlapping entries as the strings move to the glissando figures. This scale was chosen for its palindromic structure and mirrored nature of the intervals of chords moving in contrary motion as a second musical interpretation of expansion (see figs. 4.4 & 4.5).

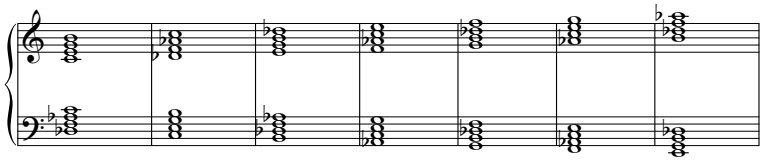

Fig. 4.4 – Chord progression in section B – sketch.

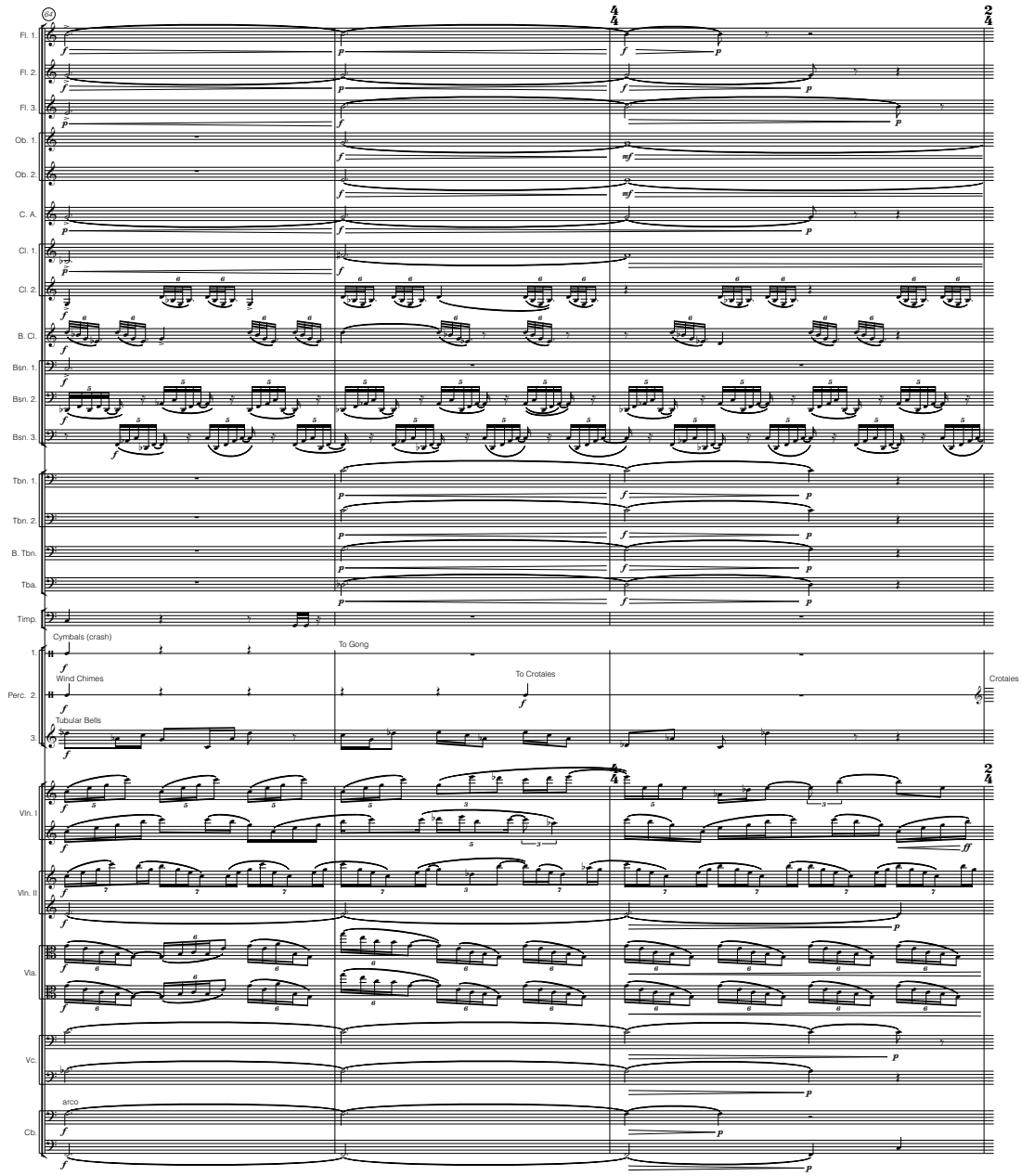

Fig. 4.5 – *Monolithos*, score (bars 64-66 – transposed score).

The tone gradually shifts into one aiming to evoke alarm, reflecting the narrative program's arrival at the point of no return for the possibility of life in the universe. A disjointed descending figure in the upper strings (bar 75 – see Fig. 4.6) is followed by the downward glissandos in the harp (bar 76).

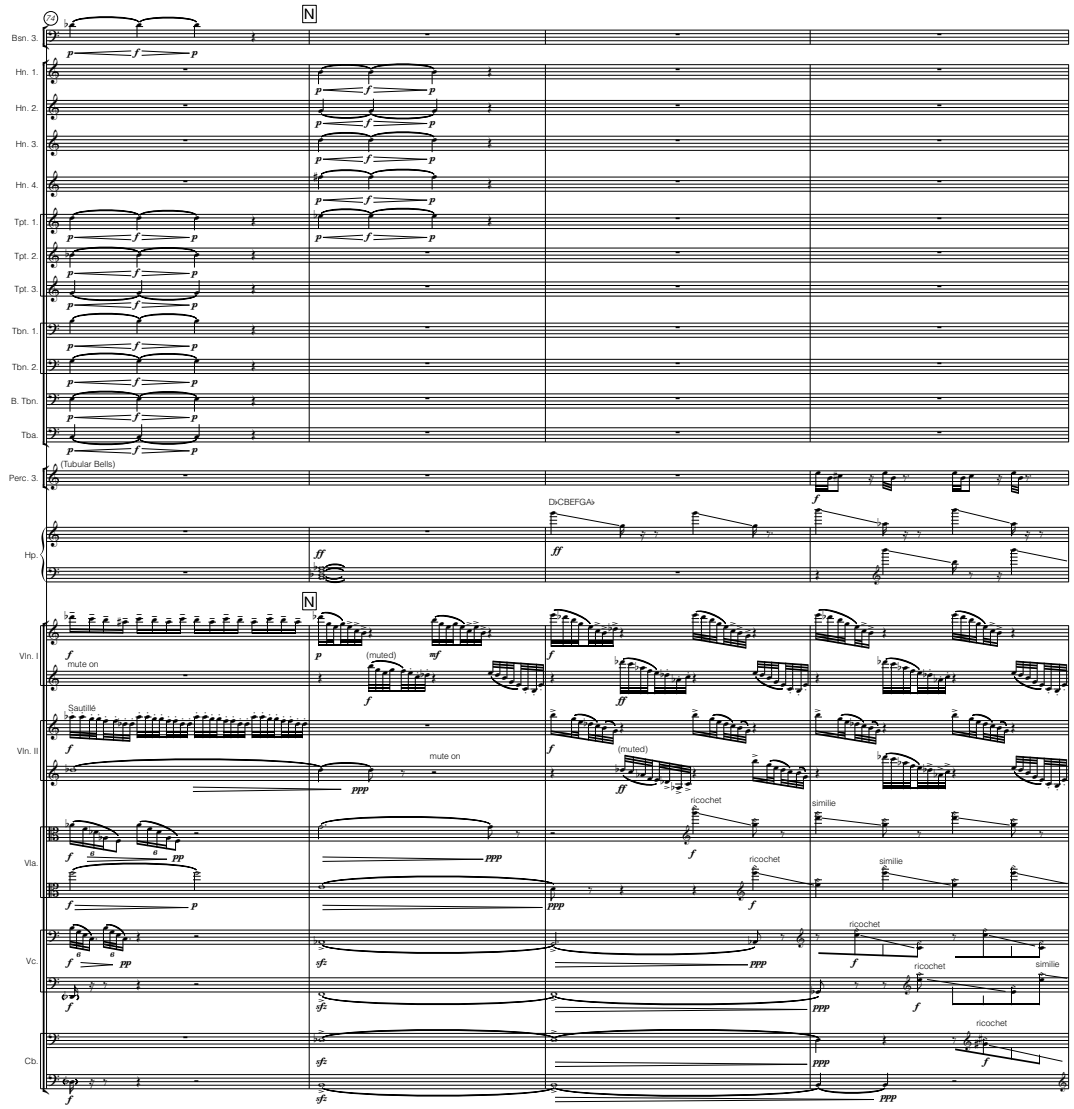

Fig. 4.6 – *Monolithos*, score (bars 74-77 – transposed score).

The glissando motion filters down through the lower strings (from viola down). Conceptually, the expansion (of matter) is now at the peak of the point of no return, and the downward glissandos now travel upward, continuing the intended alarm-like quality in the opposite direction and gradually fade, as if to suggest the subject has passed, and is continuing to move further away. As the flutes climb to their highest peak, the final cluster (diatonic C double harmonic major) attacks at forte, receding and swelling back to fortissimo twice, intended to express a final, prolonged yell of terror in the face of an infinite void (see fig. 4.7).

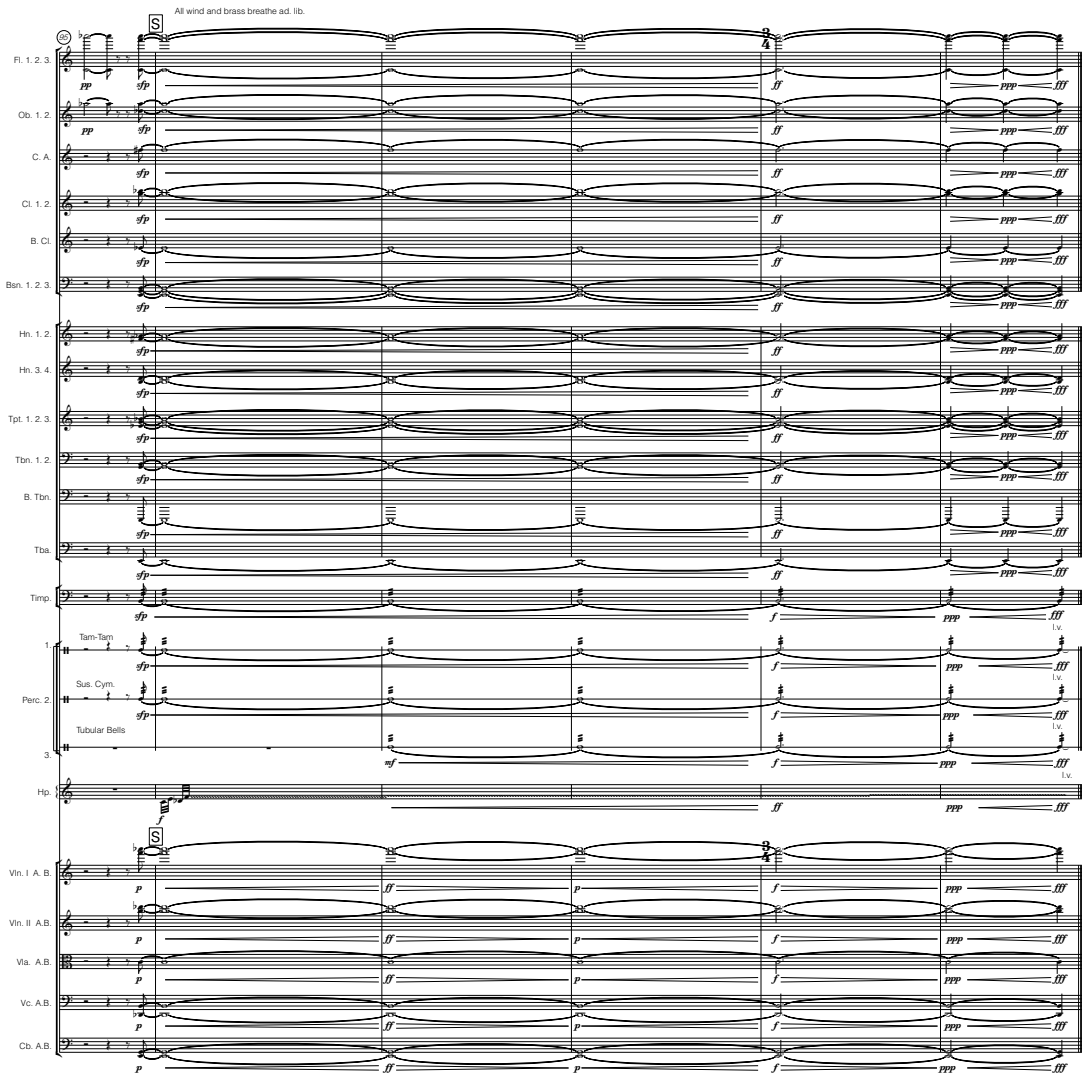

Fig. 4.7 – *Monolithos*, score (bars 95-100 – transposed score).

This piece was written following an invitation to a workshop with the Hallé orchestra, an event that was cancelled due to the Covid-19 pandemic. As a result, it is currently unperformed, leaving a reduced opportunity to reflect the full effectiveness and impact of the work. With respect to the processes followed to develop pitch material outwards, the use of two different methods worked well in establishing a different feel for each section. The stepwise pitch movement of the first section gave rise to chromatic clusters and suited the aim to create a steady, measured movement outward, whereas the double-harmonic major of the second section created harmonic complexity by way of movement through mirrored intervallic chords.

The dark quality I perceive this harmony to have suited the programmatic narrative and an intended tone evocative of alarm and distress.

INDIRECT

xiii. His Black Box

Written in response to the poem by Jessica Nwigwe. This work seeks to integrate a backgrounded mediation of the poem with respect to notions of spacetime with a foregrounded visceral response to the text through word-painting and use of Messiaen quotations. It is an example of indirect influence and positioning of a scientific stimuli within a piece with an entangled multivariant meaning.

Other Tongue 2019

Year 10,11

Jessica Nwigwe, St Bede's College Manchester, French

"Je vais vous manquer tellement", elle chuchota,
Comme elle a tiré son fils dans son étreinte
chaleureuse pour la dernière fois,
Larmes salées roulant sur ses joues
Et éclaboussant ses pieds nus.
Ces incontrôlables,
Spontané,
Et des larmes de joie inattendue.
Sa boîte noire, sa guitare usée,
Son journal rempli de souvenirs,
Ses photos préférées de son défunt père:
Ceux-ci étaient déjà stationnés par la porte
ouverte,
En attendant d'être onbragé du soleil d'été chaud,
Par la botte d'un taxi jaune.

Les oiseaux gazouillis encerclaient sa maison de
campagne,
Chanter sa chanson d'adieu.
Les voisins se tenaient dehors,
Agitant à lui comme il a laisse aller des bras
temblants de sa mère
Le chauffeur lui sourit,
Comme pour le rassurer qu'il n'y avait rien à
craindre:
Il a juste dû suivre ses rêves.
"Ici, je viens, l'Amérique,"
il a crié par la fenêtre de son taxi,
Comme le vent soufflait ses longs cheveux noirs
loin de son visage.
"Le voyage en Amérique est très long, épuisant et
dangereux,
Mais c'est mon rêve de toute une vie d'aller."
"Bien qu'une chose soit absolument
certaine,"pensait-il à lui-même:
"Je me souviendrai toujours de ma patrie"

"I will miss you so much," she whispered,
As she pulled her son into his warm embrace for
the last time,
Salty tears rolling on her cheeks
And splashing his bare feet.
These uncontrollable,
Spontaneous,
And tears of unexpected joy.
His black box, his worn guitar,
His diary filled with memories,
His favorite photos of his late father:
They were already parked by the open door,
Waiting to be chilled by the hot summer sun,
By the boot of a yellow cab.

The chirping birds encircled his country house,
Sing his farewell song.
The neighbors stood outside,
Waving at him as he let go of his mother's
tembling arms
The driver smiles at him,
As if to reassure him that there was nothing to
fear:
He just had to follow his dreams.
"Here I come, America,"
he shouted through the window of his taxi,
As the wind blew his long black hair away from hi
face.
"The trip to America is very long, exhausting and
dangerous,
But it's my dream of a lifetime to go. "
"Although one thing is absolutely certain," he
thought to himself:
"I will always remember my homeland

Fig. 4.8 – *Other Tongue* (Nwigwe, 2019).

After the first reading of Nwigwe's work, several phrases kept returning to me – in particular, 'sa boite noire' or 'his black box'. The double meaning of these words struck me as apt, since

the poem captured a pivotal moment in the protagonist's life. It also reflected the festival's[42] theme of migration – this time in meaning, and (mis)translation.

My reading found the poem to have an in-and-out of time quality. It felt like moment perfectly recorded, akin to a slow-moving picture but alive with the sensorial information that repeated itself endlessly as the memory was revisited throughout the protagonist's life. I chose a proportional score to give that sense of being in-and-out of time, a measure of freedom within something fixed. Although a tempo is given, this method retains implicit potential for contraction or expansion.[43]

It is perhaps important to preface the rest of the discussion of this work with a comment on the use of text in my practice. Historically, I have avoided setting the works of others, preferring to write my own texts.[44] Like other pieces in this portfolio, I view this work as a specific musical

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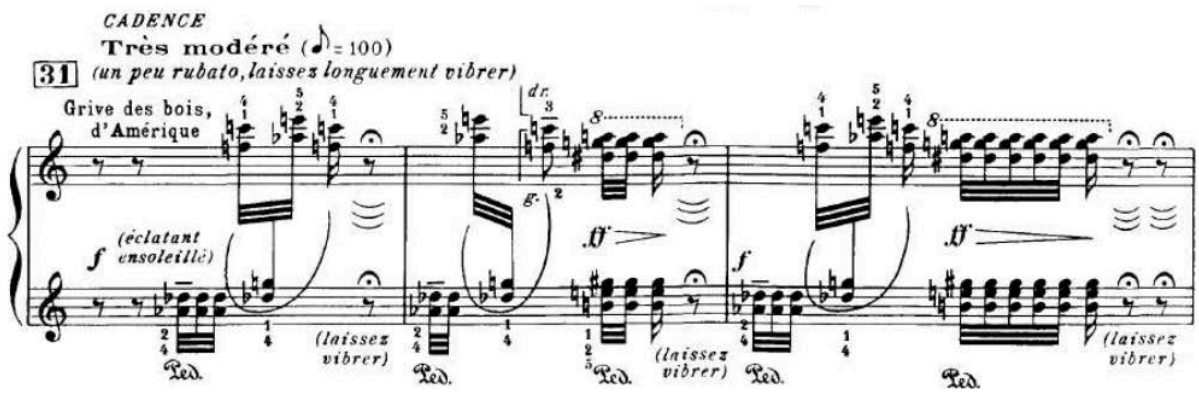
[42] I was commissioned to write this piece for Psappha by the New Music Manchester festival, on the theme of migration and displacement. I chose Jessica's poem from a selection presented by the festival.

[43] As opposed to traditional scoring, which due to metric conventions including choice of subdivision, invites an expectation of visually suggestive tempi. Since proportional framing places more emphasis on the relationships *between* the sounds, it therefore grants less weight to the individuality and separability of each sound when contrasted with typical scoring methods. In proportional scoring, preceding sounds have a particular importance since performers must use these to judge the value of each subsequent sound. Even with a given tempo, the absence of a regular pulse makes performance an ongoing act of perceptive, temporal negotiation.

[44] For three reasons. Firstly, the idea of taking a completed artistic work and introducing this fixity within a living compositional process has never felt right. I generally prefer malleability on both sides of the equation, so that the text and the music are created together as a collaboration between two mediums that are both expected to give and take during the process. Secondly, for the same reason I do not believe it is possible to translate or 'set' science in music, neither do I believe it is possible to 'set' a poem within music. Once it has been introduced into a musical process and work, it is no longer a poem. Thirdly, (and related to the second) it is important for me to have consistency in the conception of

piece arising from a constellation of factors viewed through certain lenses at a certain time. It is therefore not a 'setting' of the poem, and in knowledge of this I have not attempted to reduce emphasis on own conceptual framing.

The work starts from the perspective of multiple timeframes and the idea of an ongoing re-visitation of the original event across the protagonist's lifetime. Each sound event is both a description of the events in the narrative, and a re-experiencing of that event in later life. For that reason, I chose to use the birdsong references in reverse position. In line 15 of the poem (see fig. 4.8), chirping birds encircle his home. In the final line, he commits to always remembering his homeland. I chose a quote from Messiaen for each of these occasions. The American-native wood thrush (*Grive des bois d'Amérique* – fig.4.9a) is heard first, since that is the birdsong he hears most times when revisiting this moment (presented between the clarinet and violin – see figs. 4.9a & 4.10). At the end of the poem when thinking about his promise to never forget his homeland, he is attempting to remember the sound of the European-native songbird (*Grive musicienne* – see fig. 4.9b) that would circle his house. Unlike the first quote however, the memory of the songbird provided by the violin is closer to a suggestion than a reproduction, a hazy and imprecise recollection of the original, denoting the time that has passed (see fig. 4.12).



identity of the works. Like all other works in this portfolio, my interpretation of this text was a response that happened in time and in context. Should I have received the text a month later I would have written a different piece. Thus, this work is informed by the text, but is not a setting of it.

Fig. 4.9a – Messiaen's 'Grive des bois d'Amérique' (American Wood Thrush) in *Oiseaux Exotiques*, piano (section 31, p.23).

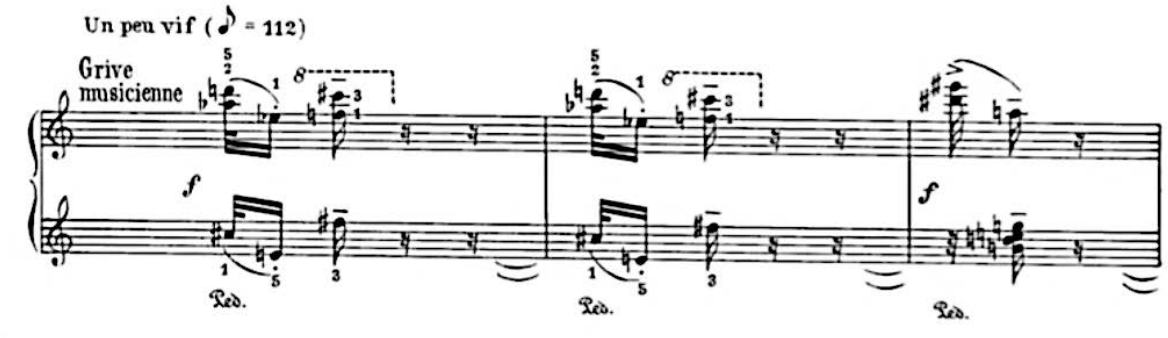


Fig. 4.9b – Messiaen*'s La Grive Musicienne* (Songbird), in *Petites esquisses d'oiseaux*, piano (p.25).

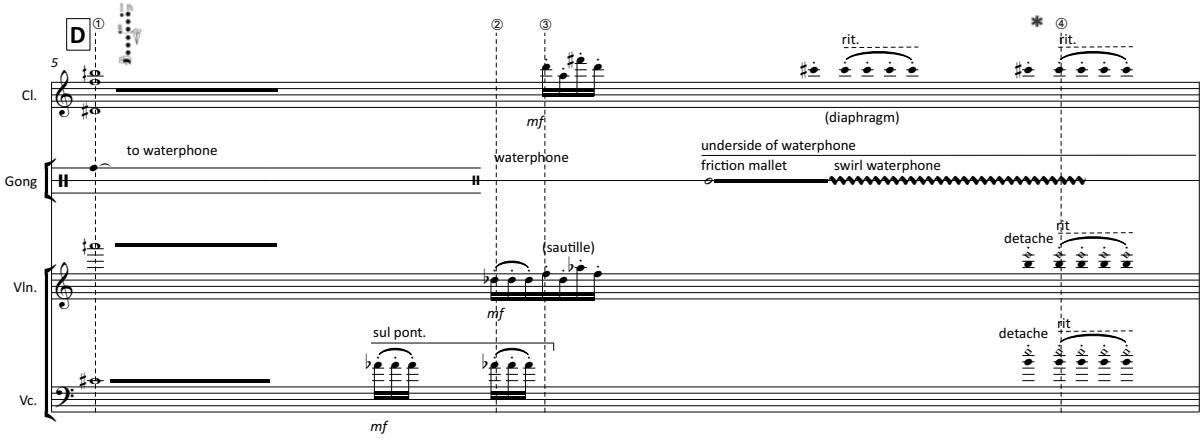


Fig. 4.10 – *His Black Box*, score, clarinet birdsong & cello tears (section D).

This present/past framing is also seen in the scoring of other events. An example is at letter H, where the cello widens the vibrato, this is intended to depict a tear rolling, that 'splashes' with the detached harmonics that follow at his 'bare feet'. This figure is repeated at J (see fig. 4.11), but widened, as upon reflection in the future, the tears take on new meaning. The protagonist comes to understand his mother's tears on a deeper level, not just sadness at a goodbye and a mother's worry as he first experienced, but as bittersweet-ness. He later considers the mix of grief and joy at watching a child come of age, the of difficulty and relief in letting go so they

may take their first steps into a lifetime of adulthood. The tears become larger in remembrance because of their significance to him and resonate throughout the piece.

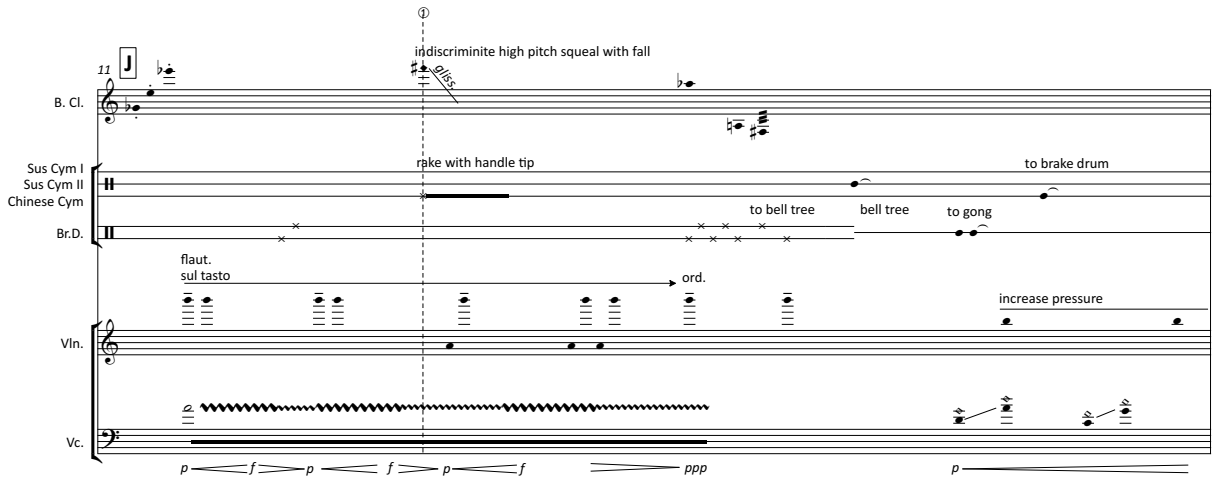


Fig. 4.11 – *His Black Box*, score, cello 'tears of joy' (section J).

Although science was not at the forefront of my mind when I initially received and began connecting with the poem, throughout the composition process I gradually became aware of how the theories of spacetime I had been immersed in concurrently with the writing process had influenced both my reading of the poem and my musical response. Of influence were three theoretical positions on the differences between the past, present and future to 'realness', with the eternalist view playing a particular role in shaping the piece. Tom Stoneham remarks of this theory of perspectives on time, 'it seems obvious…there can be no objective ground for distinguishing between these three categories: all are equal, the universe consists in a solid block of events spread out through time and space. Call this view eternalism.' (2009, p.201).[45]

[45] Of the other two views, Stoneham remarks that 'It seems equally obvious to others, usually those with a more humanist inclination who are interested primarily in what we can and cannot change, that the future hasn't happened yet, and thus that future events are less real than present or past events, all of which have happened. On this view, the universe does consist of a solid block of events, but it is

The way I responded to the poem was influenced by the idea of the eternalists' block universe as well as the unreliability of human memory and complex ways that we as organic, emotive animals synthesise this to create meaning from a perceived reality. *His black box* sets the events of the poem with layered meanings and re-renderings that happen simultaneously with the original events, inviting a temporal reality dependent on perspective.

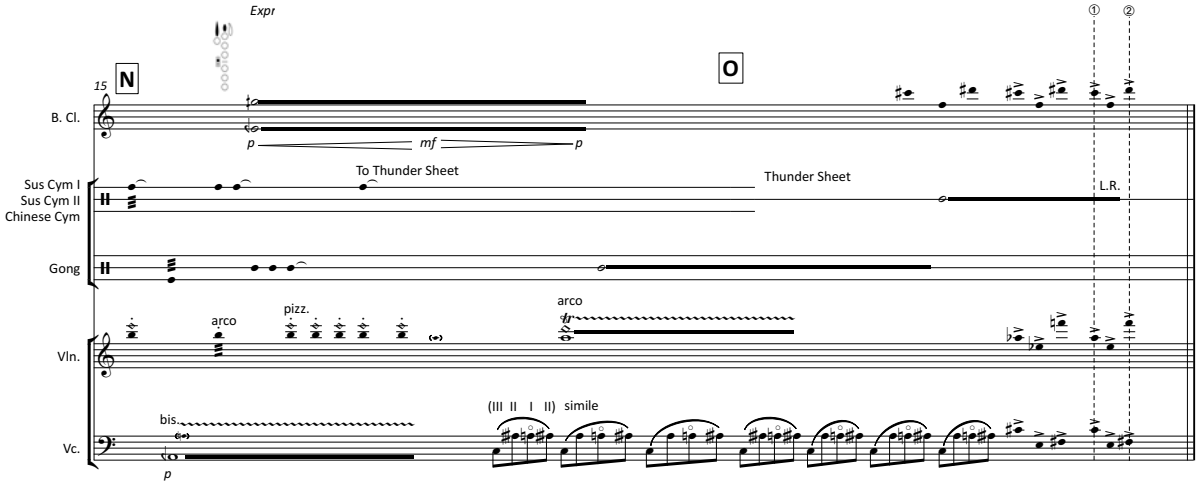


Fig. 4.12 – *His Black Box*, score, violin – a misremembered 'Grive musicienne' (section N).

Once aware of its influence on the compositional process, allowing the theory of eternalism to provide a framework through which to read and set the poem proved useful in grounding the mode of inquiry within a set of ideas. Further, it provides the work with an additional layer of meaning which, although not directly communicated to the audience, is embedded in the music. Being aware of the interplay between the framework and the poem avoids confusion with the problem of 'setting in music' something that is extra-musical, a differentiation I have

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a growing block: as more future events become present and then past, they are added to the block. Call this view gradualism. Finally, and perhaps less obviously, there is the view that only the present is real, that the future has not happened yet and that the past has irrecoverably departed…Call this view *presentism*. (pp.201-202)

attempted to make clear in the discussion of the Portfolio, since it has remained consistent in my engagement with extra-musical constructs of all types.

ACOUSTIC PHENOMENA

As noted in Chapter 3, many musical parameters are quantifiable, and music itself is a set of functions performed with frequencies or other wave-based disturbances that interact with both our physical environment and our bodies (Benson, 2007). The difference in the properties of resonance both between and within instruments in the same family was explored across two different pieces, *A Length of String*, discussed below and *Mark I* (Appendix A).

xiv. A Length of String

A Length of String looks at a juxtaposition a group of similar instruments (3 marimbas)[46] *and another, closely related instrument (vibraphone). It is a companion piece to Mark I (Appendix A), exploring combinational possibilities of resonance between three related instruments with a keyboard layout and a group vs. solo ensemble dynamic.*

This work explores ways that difference in resonance length and timbral quality can either be magnified or reduced in a percussion quartet that features three similar instruments with another, related instrument. The first section explores increased resonance length in the marimbas with bowing (fig. 4.13), together with the reduced resonance in the vibraphone when performing pitch bends.

[46] different only in range and the variable qualities specific to individual instruments.

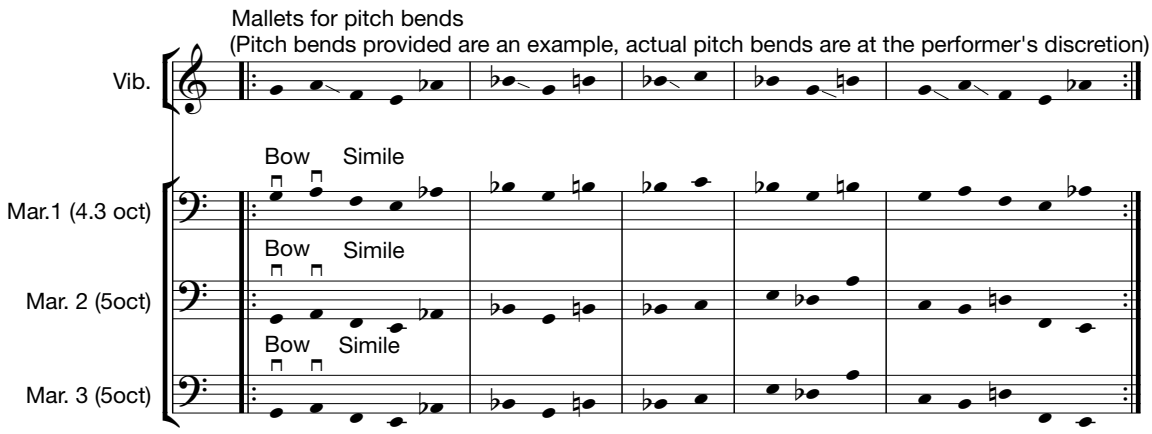
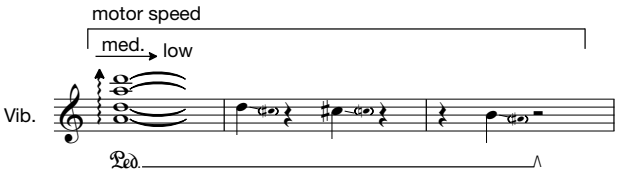


Fig. 4.13 – *A Length of String*, score, vibraphone pitch bends and bowed marimbas (Section 1).

The pitch bends move to the marimbas in the second section (see Fig. 4.14). All instruments are now playing similar shapes, however there is a juxtaposition in timbre between the struck vibraphone and the bowed marimbas. The audible oscillations in the vibraphone also contrast with the dry, steady quality of the marimbas.

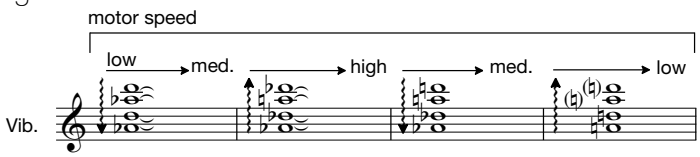
Vibraphone:

Fig.2.1



Repeat structure of Fig.2.1 with the arpeggios in fig.2.2 (below), alternating direction of arpeggio (up or down) and speed of motor (low-med, med-high, high-med etc.). Choose one of the notes in the arpeggio to create a falling line toward the next arpeggio using pitch bends in tone or semi-tone steps down (as in fig.1). Take time in between arpeggios to allow the sound of the chord to nearly die out, but avoid regularity – i.e. allow different lengths of time between each arpeggio. Lots of space is key as the marimbas will need that decay time for their pitch-bends to emerge in increasing audibility. You can choose to leave them to play the pitch bends for a time once they are playing independently of one another.

Fig.2.2



All of the notes in the arpeggio can be included, but you can also choose not to re-sound those that were played in the previous arpeggio.

Marimbas I,II,III:

In unison for the first few cycles as in fig.2.3, then begin to diverge toward an approximation of fig.2.4, where crotchets represent a single beat of the vibraphone motor. This should be slow, but will still likely be too fast to bow each beat even between 3 players, so come in again when it is practical. Staggering should be attempted but instances of synchronisation are fine.

Fig.2.4

Fig.2.3

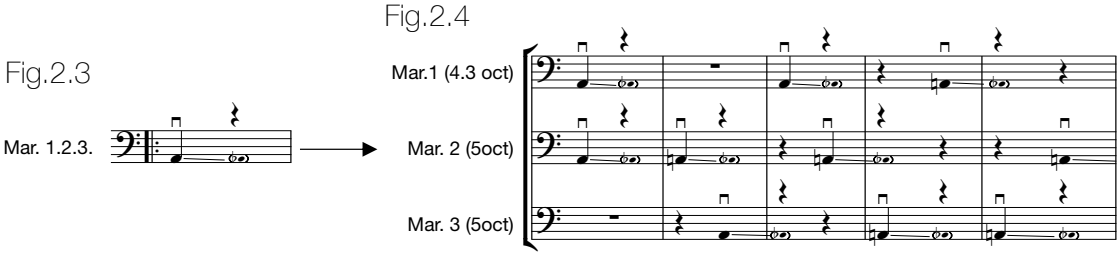


Fig. 4.14 – *A Length of String,* score, pitch bends (Section 2).

The third section explores a progressive change in resonance length in opposite directions between the two instrument types. For vibraphone, the length progresses from shorter to longer. Beginning with the motor off, no pedal and using dead strokes the score then instructs the performer to begin changing dead strokes to muted or dampened strokes, adding pedal, moving to open tones, motor on at a low speed, and finally increase the motor speed. This

time the marimbas are moving from longer to shorter resonances through many of the same techniques in reverse.

In the final section, all instruments are bowed, with harmonics introduced in the vibraphone line with the motor at a low speed. I found this grouping to provide the most cohesive, if not blended sound of the piece. The bowed harmonics appear to reduce some of the characteristic vibraphone timbre that together with the low bowed notes of the marimba, sound as if they could be overtones that originating from the same or similar instrument.

The change in resonance length and timbral quality through the setting of similar or different duration-changing techniques against each other provided interesting effects on ensemble blend and received positioning of sound between the instruments (foreground/background or blended). Perpetually sustainable techniques such as rolls were which were excluded from this work that focused on ways to increase or reduce non-sustainable sounds but could be used in addition to other techniques to explore these ideas further, such as more short, dry resonances, different mallets and preparations. The indeterminate scoring gave a malleability to the material (particularly with respect to time) that proved useful for the exploration of the ideas as a joint activity between members of the ensemble and myself.[47]

PROCESSES

Two pieces in the Portfolio draw from the processes of science for the construction of compositional form and structure. They are *Mark I* (Appendix A), and *Scaffold II*. Both employ obscured theatrical narratives and internalised or externalised performance art approaches to

[47] It is not my intention that any future performances would need to discuss the piece with me, nor refer to any previous recordings of the work, but they can, should they wish to. The purpose is to allow for individualised exploration by each ensemble. As expressed by Richard Glover on his *Logical Harmonies* (2019) release 'What I enjoy about process is the ability to build a concept, which - if the concept is right - then needs no tinkering from me.'

imitate the process of scientific study by exploring instrumental sounds under conditions set by the score.

xv. Scaffold II

The act of 'scientific' investigation is explored through performance in this work that uses ideas of 'hypothesis/experiment' as a basis for structure and form. The pianists work through a range of sounds on the piano from very 'resonant' to very 'percussive', and includes an internalised, dramatic performance aspect.

Music, Natural Magic, and the Royal Society

This piece is both a homage to, and exploration of the overlapping meanings and definitions of performance, magic and science in the 17th century and the transition from natural philosophy to what we understand as science today.[48] The musicians are asked to approach the performance as if they are presenting natural magic to an audience (producing sympathetic resonance of the strings with each other), an additional performative aspect that is meant to inform the pianists' approach but not be theatrically overt. The narrative presented to the performers is that the musical material they are playing is a demonstration of their 'attempt to understand and control this magic' by separating the piano into its component parts and exploring each part systematically. The purpose they are asked to internalise is that they are seeking to bringing these forces under their control, so that, having been 'tamed', magic could be brought into the realm of science.

The difference between the approach of *Mark I* and this piece is that the former includes observation, categorisation, and discussion as part of the piece, and can build on its artistic findings at each performance. In *Scaffold II*, it is not the act of investigation but a *performance* of investigation that is being reproduced.

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[48] Gouk (1999). Further information on the historical themes underpinning this work are provided at the end of this section.

The program is as follows: we start with a 'hypothesis' that the piano can produce resonant sounds that could be categorised as 'pitch sound' – a sound with partials that complement each other in additive ways (see fig. 4.15), as well as those that can be described as closer to 'noise sound' – sounds that involve more complex partials and sound more 'percussive' (see fig. 4.16).

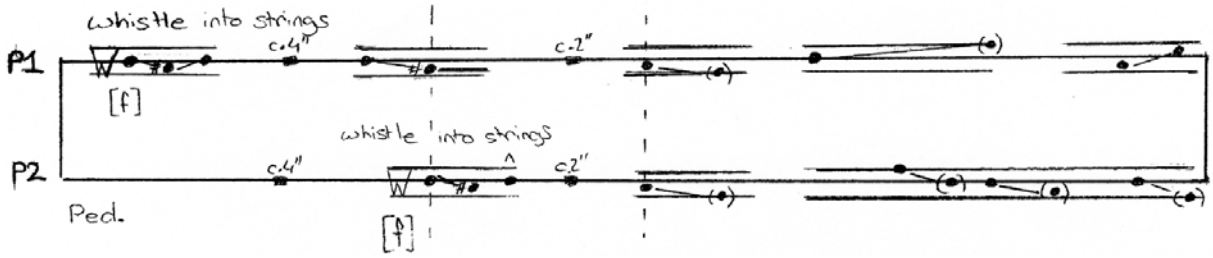

Fig. 4.15 – *Scaffold. II*, Piano (Beginning to end of 'A'). Whistling into the strings to produce a 'pitch sound'.

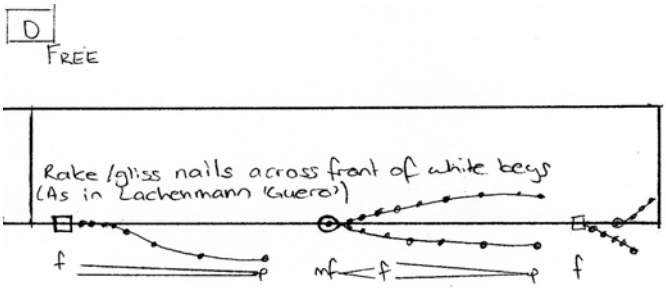

Fig. 4.16 – *Scaffold. II*, Piano ('D'). Percussive 'noise' sounds.

The performers are given the objective to 'present' the purest form of pitch-sound[49] currently discovered in the narrative – the whistle into the strings of the piano. This establishes an outer-limit for the research. Following this, the performers begin with most pitch-less sounds (the

[49] A pitch sound closest to a sine wave – specifically one that is devoid of a percussive attack on the string.

nail-raking across the keys of fig. 4.16), gradually moving through sounds with elements of both, toward the sounds that produce greater resonance (see fig. 4.17), arriving back at the whistle to compare their findings to the anticipated outcomes of the hypothesis (see fig. 4.18). Also included in the programmatic narrative is the framing of 'researchers sharing findings', modelled musically in the invitation at 'S' for the performers to 'continue their dialogue' by responding to each other's improvised development of material presented in figure 'R' (see fig. 4.19).

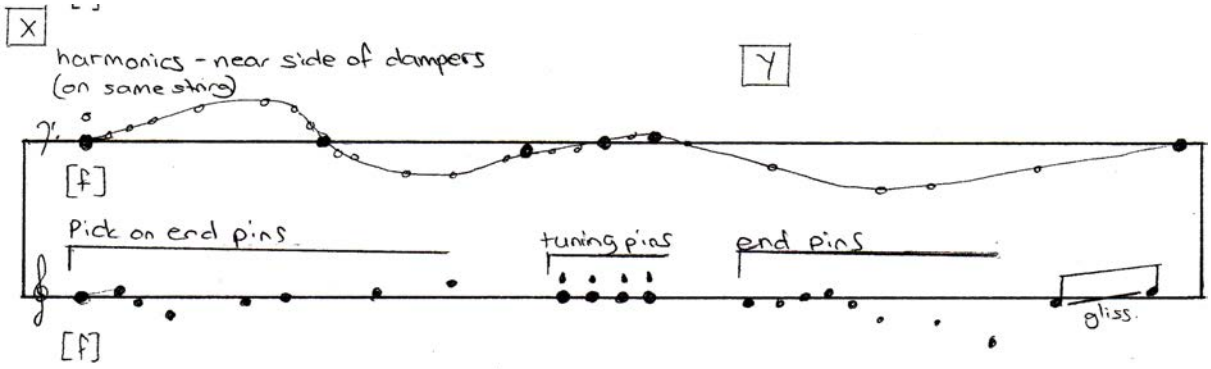

Fig. 4.17 – *Scaffold. II*, Piano ('X' and 'Y'). Performer 1 'finds' more resonant sounds (string harmonics), whilst performer 2 'experiments' with the end and tuning pins.

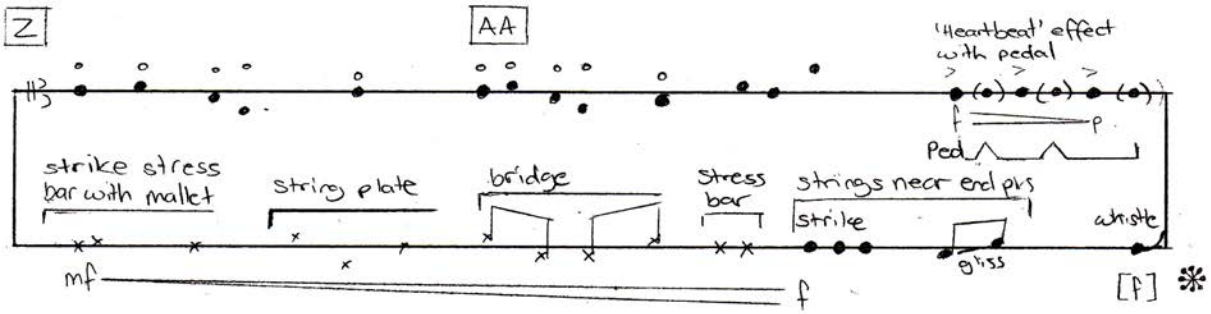

Fig. 4.18 – *Scaffold. II*, Piano ('Z' to end). Setting of outer limits: highly 'pitch-aligned' sounds of performer 1's harmonics with the highly 'noise-aligned' sounds of Performer 2's mallet strikes against the wooden and metallic parts of the piano.

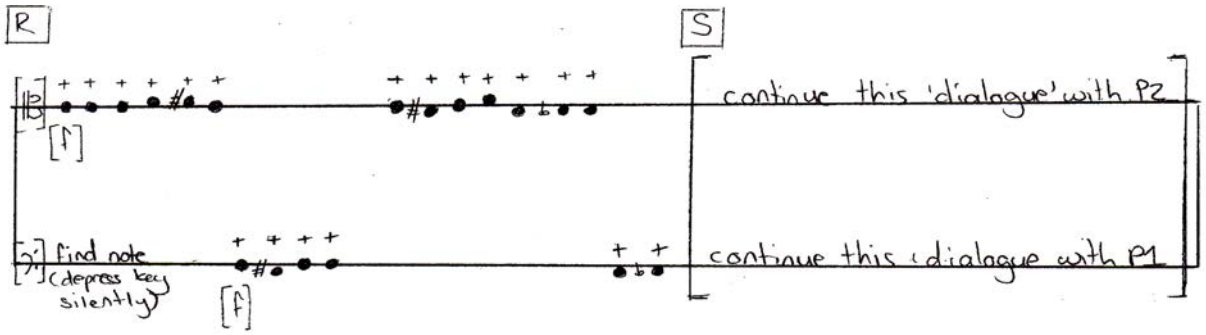

Fig. 4.19 – *Scaffold. II*, Piano ('R' and 'S'). Musical 'dialogue' between researchers as analogy to 'sharing research findings'.

The pianists engaged effectively with the obscured aspect of performance, and I found this approach gave a sense of cohesion and purpose to each of their actions. Whilst the audience may not be explicitly informed of this aspect of the performance, the result was noticeably mediated by this additional layer, something that would contribute toward an experience of the piece regardless of awareness of this fact. Drawing from the act of scientific investigation not only for compositional strategies but also as a performance model therefore proved to have an interesting impact on the way the performers approached the musical material, their interactions, and the performance setting.

Scaffold II – further information on the themes informing the work:

By around 1600 an understanding of science 'chiefly denoted a body of theoretical knowledge or doctrine about a specified subject', wherein 'the sciences were individual branches of knowledge acquired by study, and were concerned with systematic truths embodied in texts' (Gouk, 1999, p. 9). To distinguish the use of these terms from their modern meanings, Gouk clarifies that the term 'scientist' as *practitioner* did not exist, and 'the idea of *practicing* science would have been utterly incomprehensible to anyone in this period' (Gouk, 1999, p.9).

This hierarchical positioning of theory above practice is similarly important to understand the use of the term 'music' and 'musician' within this context. As Gouk (1999) clarifies:

> Even though music's affinity with mathematics ensured its place within the arts curriculum, this Boethian view of music did not automatically promote the *art* of music as being academically worthwhile. Instead, it portrayed the 'true musician' as a philosopher who understands 'the underlying structure of the universe and the speculative principles on which music is based.' (p.46)

This distinction is critical, since it was introduction of an experimental mode of inquiry that facilitated the shift to the modern scientific method. Knowledge of instrumental techniques producing complex resonances were granted authority by their introduction into the academic setting by natural philosophers (Gouk, 1999, p. 54). These demonstrations, their ability to make occult forces visible and thereby neutralise them as 'science' in turn granted authority of the emerging field of experimental philosophy.[50] Although the production of knowledge by instrumental practitioners would remain uncredited and their roles and as musicians divorced from their impact on the emergence of experimental philosophy,[18] the merging of knowledge from music theory and practice played a key role in the birth of modern science, and the impact of that synthesis between theory and practice is worthy of consideration in the ongoing, cross-influential history of these disciplines.

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[50] 'That strings could be made to resonate in complex and puzzling ways was a well-established phenomenon that instrument makers and practitioners had been experimenting with since the sixteenth century. Only now, however, was this phenomenon recognised as a 'discovery' germane to mechanics and natural philosophy, because it was publicly communicated by men with sufficiently high social and intellectual status. Once detached from the instruments, the practitioners and the sphere of musical practice that had made such a phenomenon visible, the properties of vibrating strings could be transferred to the realm of natural philosophy and thereby gain the status of true scientific knowledge.' (Gouk, 1999, p.54)

CHAPTER 5

Collaboration with Scientists

This chapter details the three collaborative series in the project. The first was with Dr. Kirstie Andrews, Senior Lecturer in Engineering Materials & Biomedical Engineering at Manchester Metropolitan University and explored concepts responding to the human nervous system. The second was with Mathias Brust, Professor of Chemistry at the University of Liverpool and covered various aspects of Brust's research, including the properties and application of gold nanoparticles and a prospective chemical energy conversion process. The third involved individual health data projects such as Connected Health Cities (CHC) and the International Severe Acute Respiratory and Emerging Infection Consortium's ISARIC4C UK COVID-19 group.

COLLABORATIVE SERIES – Dr. Kirstie Andrews

xvi. Rennervate

This piece was informed by a collaboration with Bio-Chemical Engineer Dr Kirstie Andrews at the MMU. It uses motivic transformations and determined versus free composition methods to programmatically explore ideas of linear versus indeterminate and directional[51] *forms of growth.*

Andrews created artificial scaffolds to study the growth of axons, with the view to finding solutions for damaged neural pathways. In early conversations Andrews introduced her work by giving an account of her process from the examination of prior theoretical models through to the creation of more successful scaffolds based on her own hypothesis.

[51] Directional growth is here described as a pattern of movement that progresses in a particular direction over time but includes instances of movement away from the target site. Some scaffolds built by Andrews resembled chaotic spiralling structures, but in aggregate consisted of more sections aligned in a particular direction.

As this was a field of science I had no prior knowledge of, moving compositionally through this narrative in a programmatic manner gave me a foundation on which to develop an understanding of the facts of the system and develop a compositional response. *Rennervate* (an invented contraction of re-nervating) is therefore a programmatic piece informed by a personal, historical account of Andrews' early research, using some compositional inferences to the underlying scientific concepts to express this narrative in music[52].

Early research involved a prior hypothesis that regular, road-like channels would offer the best environment for long, directional axon growth. Andrews discovered that this approach resulted in poor results in the lab - not just that the axons did not grow with regularity but that they did not grow much at all. Struck by the often-irregular pathways of growth in nature, (such as the tendrils of a strawberry plant, roots, ivy etc.) Andrews considered whether a spiralling surface would produce better results. The creation of spun scaffolds proved the theory plausible. Axons grew better across the irregular scaffold, and best across a scaffold with a degree of directionality[51] built into the looping structure.

Rigidity and 'road-like' parallel channels are expressed musically by the marimba (representing the scaffold) and occur in bar 2 as a dyad descending regularly by octaves. The dyad's interval of a fifth was chosen for its common association with an 'open' sound, which I related to the idea of a channel (see fig. 5.1).

[52] Similar biographical approaches have been explored by other composers, such as Lynne Plowman's work *Seven Dark Lines* (2016) mentioned in the practice review (Chapter 3).

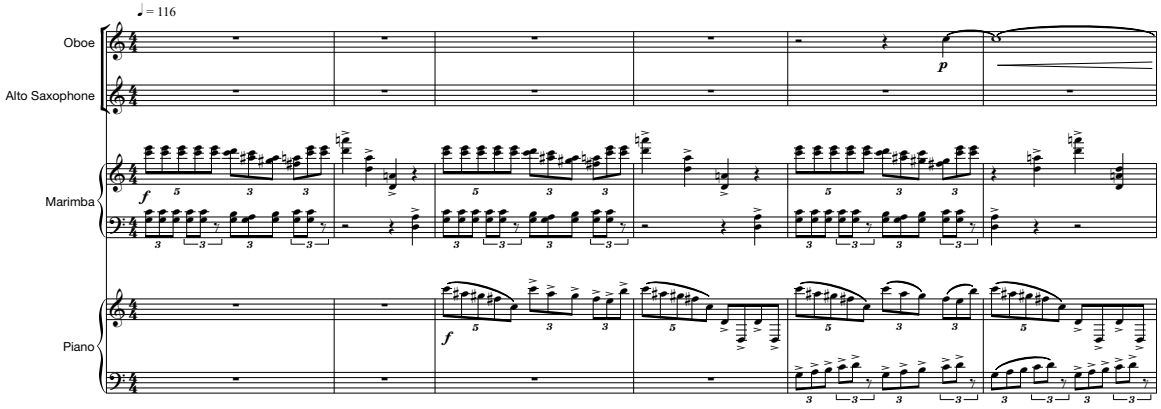

Fig. 5.1 – *Rennervate*, score, 'road-like channels' in marimba & whole-tone tetrachord in piano (bars 1-6).

A motif of a descending whole-tone tetrachord (C, A♯, G♯, F♯, C), used for the regularity in spacing between the first four pitches, repeats throughout the piece in evenly spaced tuplet rhythms (see fig. 5.1). This motif and the angular phrasing in this section is meant to represent the rigidity in both the will of the researcher and the predicted best growth conditions of the axon. The piano's role is to introduce the scientist as a factor in the environment and the beliefs guiding the decisions that are being made throughout. The broken, more aggressively articulated restatement of the first four pitches in the triplets was used to suggest a fixed approach leading to a type of dogmatic stubbornness. Like the way an adult might repeat a direction to an uncooperative child more firmly and with greater emphasis in spacing and articulation in the hope that the child will act on the will of the adult, the figure is repeated with greater space between each note, and stronger articulation. The recurrence of the C♮ at the end of the quintuplet is meant to hint that the process should continue repetitively down the octave, however, second triplet introduces pitches outside the motif previously given. The idea behind this is that even as the researcher believes they are progressing with the same ideals and fixed methodology, unconsciously they are being affected by the results of the interaction with the results and are changing their approach over time.

The oboe and alto saxophone are conceptualised as 'axons', and growth potential is musically indicated by the increased duration of rhythm (see fig. 5.2). Successful, directional growth characterised by movement of pitches up or down (see fig. 5.3).

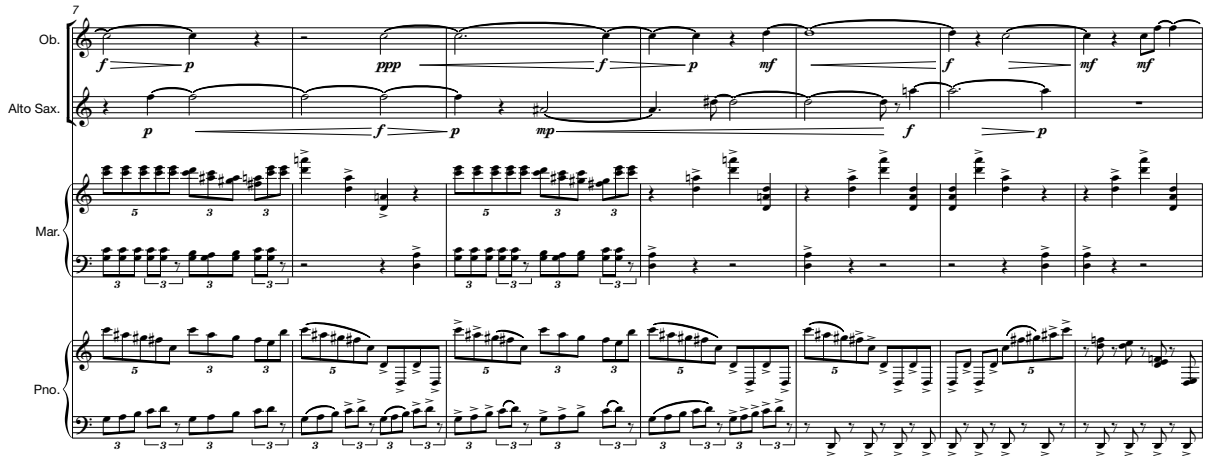

Fig. 5.2 – *Rennervate*, score, Oboe & Alto Saxophone increased rhythmic length (bars 7-13).

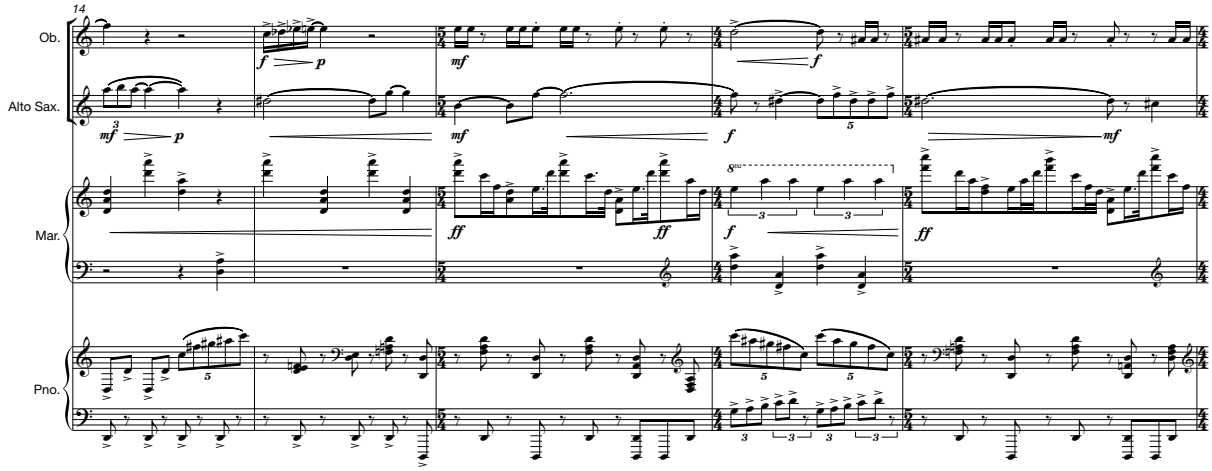

Fig. 5.3 – *Rennervate*, score, directional pitch movement beginning in oboe (bars 14-18).

Changes in phrasing as well as reduction of material throughout this section are used to illustrate how the early researchers might have imagined the practical research taking place: modifying individual parameters of each generation of scaffolds with a streamlining of the process over time – fortifying useful features while removing those assumed redundant. Reduction of material also imagines this type of rigidity as a feedback loop present between the thinking and process that results in the dogmatism becoming stronger over time as the growth of the axons prove unresponsive. The failure of growth presented in this section,

illustrated by a progressive shortening of duration and reduction of movement in pitches as if 'sputtering out' (see fig. 5.4) was based on Andrews' practical findings of this theoretical model.

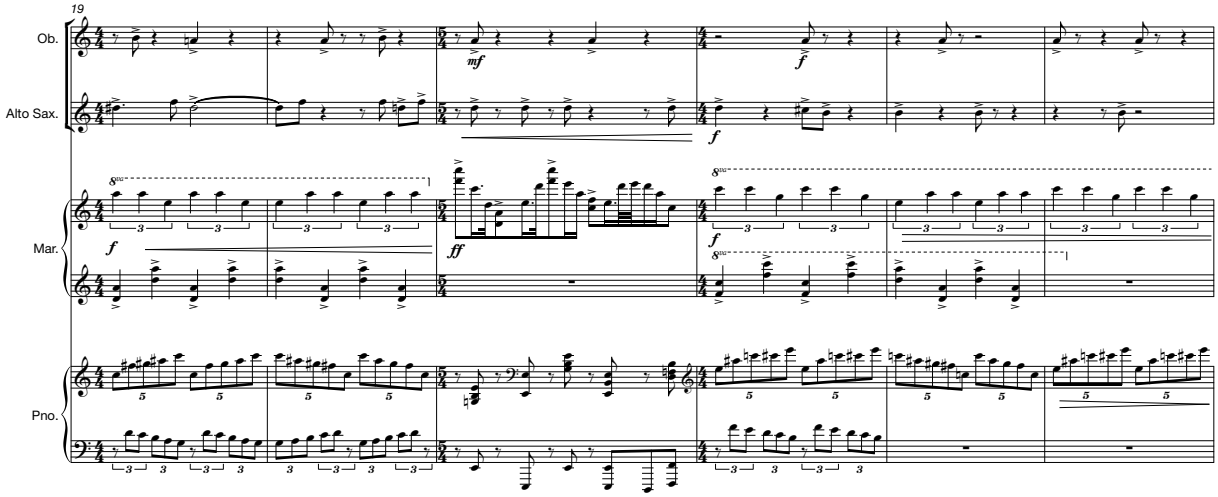

Fig. 5.4 – *Rennervate*, score, Oboe & Alto Saxophone (bars 19-24).

The next section of the piece (see fig. 5.5) explores Kirstie's observation of growth of axons under 'normal' conditions. The marimba's movement is more 'unexpected' in its directionality (intervallic movement of pitches as well as direction – up or down) and evenness of progression (rhythmic duration and rests). Free composition was chosen as a methodology suited to this idea of growth driven by unseen conditions, and this juxtaposition with the previous process-based composition mirrors a similar change in scientific methodology.

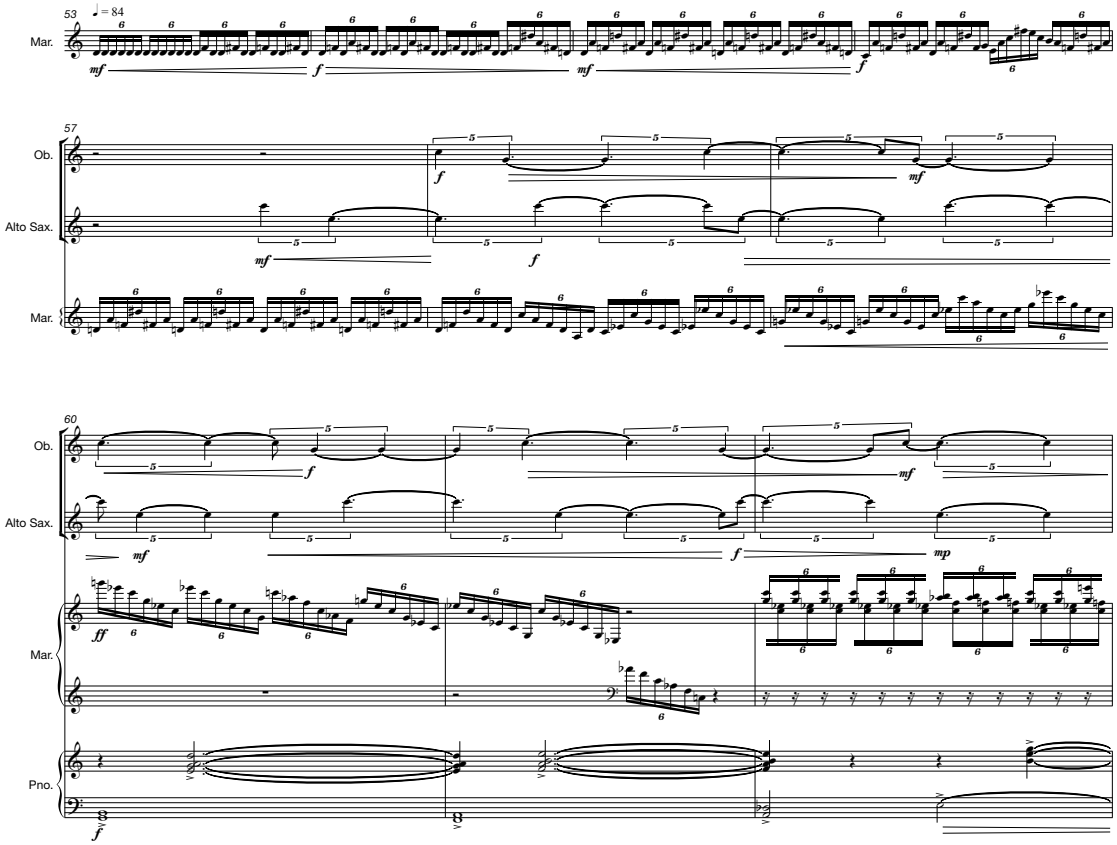

Fig. 5.5 – *Rennervate,* score (bars 53-63).

The subsequent section presents the idea of 'polarity changes', where the stopping and starting of piano and marimba materials describe the opening and closing of ion channels, before returning to the structural concerns outlined previously.[53] Further variations of the motif either with or without the chromatic material introduced in the 'natural growth' section are explored by the marimba, intended to express the idea of different types of scaffolds being developed (see fig 5.6). Transformations include augmentation of the original triplet rhythm in the marimba in bar 76 and glissandos in bar 78 that suggest a doubling back on itself (looping). The resulting 'growth-type' over this material is demonstrated by the movement of the pitches

[53] Factors governing choice of pitch and rhythm existed, but in the interest of brevity will be omitted from this discussion.

in the oboe and saxophone within the partial whole-tone scale related previously to an idealised, even progression of growth (see fig. 5.6).

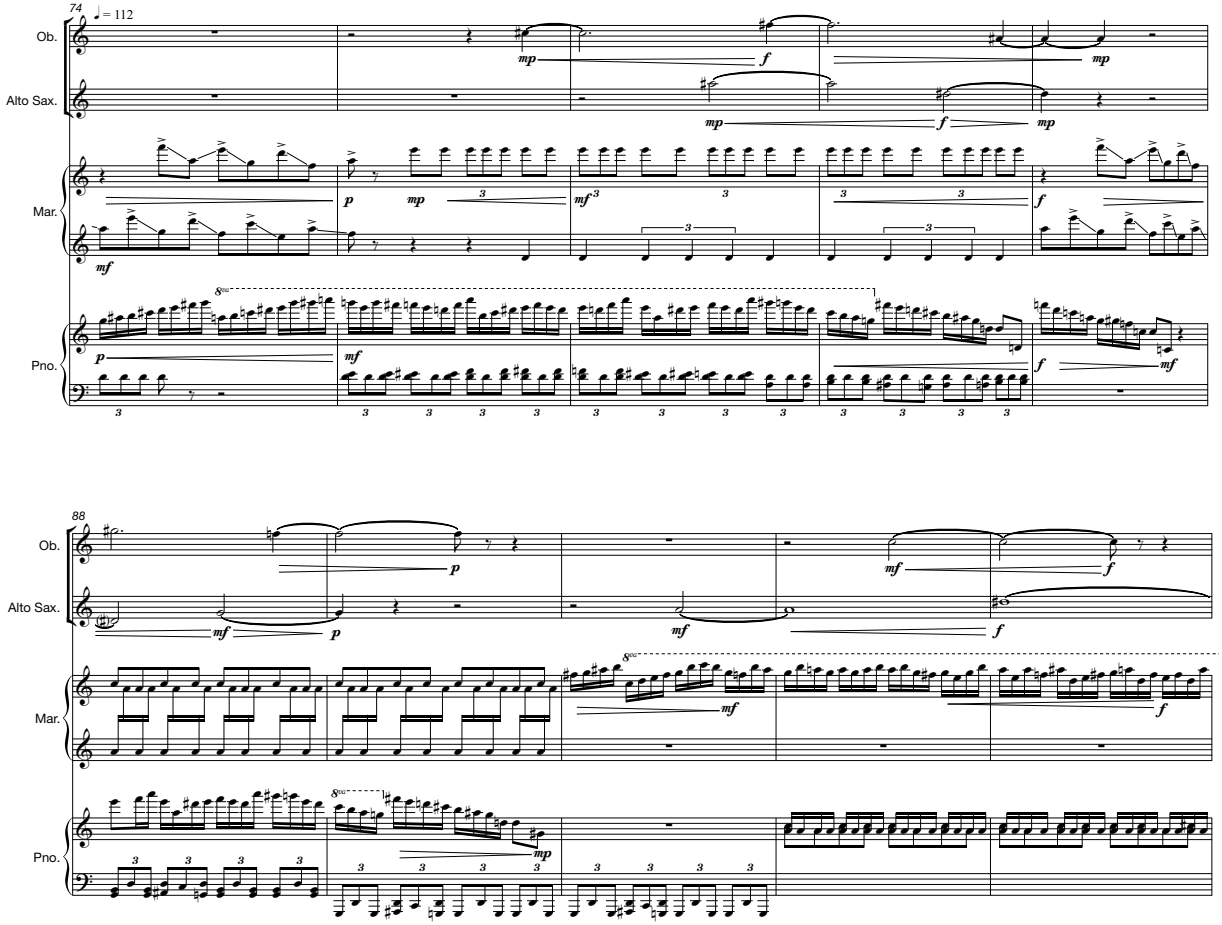

Fig. 5.6 – *Rennervate*, score (bars 74-78 & 88-92).

The final section of the piece demonstrates a continuation of this method of adjustment, presenting yet another version of the scaffold. This version, like those leading up to it, is seen to produce some reliable results of 'growth' (duration of pitches in the woodwinds). This has been achieved by a successful combination of regularity (of rhythm & motion of pitches up & down) with other opportunities provided by a more varied collection of pitches as introduced by the explorations into hypothesised 'natural' conditions.

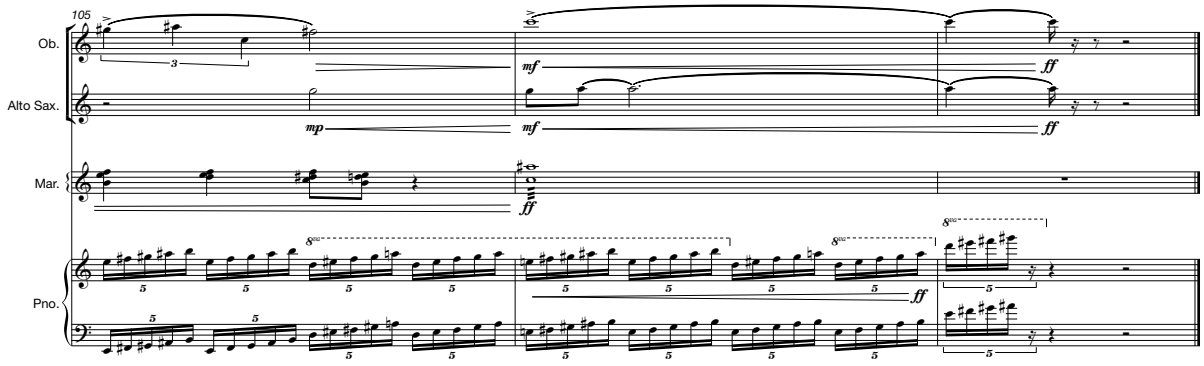

Fig. 5.7 – *Rennervate*, score (bars 105-107).

Relating the music to a narrative process aided in the creation of a dialogue between Andrews and myself. By discussing the work together throughout its construction,[54] we were able to develop a representational language with an accompanying discussion. This gave us confidence in the method, which we took forward to our next piece, *At the Node of Ranvier, where* we would explore Andrews' research in further detail.

xvii. At the Node of Ranvier

This piece employs rules for performer interaction, augmented piano and tape to construct a process of signal transfer informed by the nervous system when working, damaged, and across synthetic scaffolds.

When commissioned to write for Explore Ensemble and the Piano Machine[55] I immediately related this augmented instrument to the idea of a nerve scaffold. The timbral quality of the vibrating phone receptors between the strings of the piano evoked an association of an

[54] Andrews and I corresponded via emails, comments on a word document, midi recordings, score excerpts and in-person meetings.

[55] The piano machine is an augmentation developed by composer Patricia Alessandrini and Goldsmith's Konstantin Leonenko. The instrument was featured at the premiere of Alessandrini's *Tracer la lune d'un doigt* (2017) (Alessandrini, 2021)

intermittent and modified signal transfer for me.[56] Controlled by a midi keyboard (see Fig. 5.8), the augmentation could be played together with standard keyboard technique giving rise to 3 performance options: acoustic,[57] augmented, or acoustic & augmented[58] for most notes (for full range see fig. 5.8).

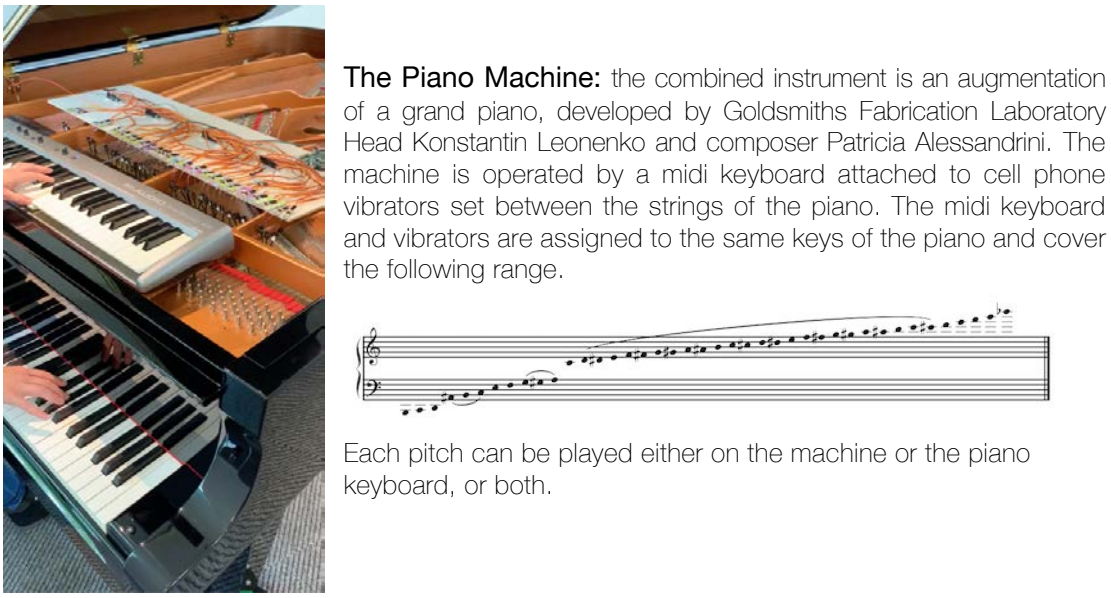

Fig. 5.8 – Pictured: The piano machine.

The score provides figures with optional musical interpretations, much of them with incomplete or scarce performance information (dynamics, articulation, tempo etc.).[59]

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[56] Informed by my personal experience with nerve damage, I found the combined acoustic and electronic timbre and irregular rhythmic qualities somewhat evocative of both this sensation and the idea of adding a synthetic object to the system as a solution.

[57] When struck with force, the piano strings interact with the vibrators, otherwise the presence of the augmentation is not audible when the piano is played acoustically.

[58] Matthew Shlomwitz's *Popular Contexts* (2010 –) similarly explores combinations of acoustic and augmented instruments by way of synthesisers and midi pads.

[59] The specificity of the notation style conceptualised as 'missing' information (information that would otherwise be there but has not been given) is to achieve a particular effect in ensemble interaction and

Sometimes represented graphically, notations were accompanied by a visual representation of the tape (see fig. 5.9). The performance notes outline rules for ensemble interaction that follow a pathway through the central nervous system (CNS) beginning with the brain (computer – placed within the body of the piano) and spine (piano – played on the keyboard by a performer) through to the sensory neurons of the hand (winds) and the motor neurons of the hand (strings).

The purpose of figures that give *some* performance information, rather than *all* or *none*, is to allude to a system that is damaged. The signals being referred to are pre-given, so free composition, improvisation or aleatoric methods were not closely comparable, but at the same time not all the information is transmitted correctly, so neither is it aligned with a fully determined system.[60]

decision-making. In keeping with the idea of signal transfer, the ensemble must choose how to relay material that is missing directions – either by finding workarounds, deciding on new parameters, or omitting some aspects entirely..

[60] The specificity in compositional system and style of notation important for reasons outlined by Christian Wolff's comments regarding *For 1,2, or 3 people* (2002), written in 1964. As recounted by Lucier, the former 'often said that his notation is the only way to get what he wants. It's not the randomness or indeterminacy causing performance practice problems, it's the feeling of two or three players coordinating and … being attentive and responsive to each other' (2012, p. 50).

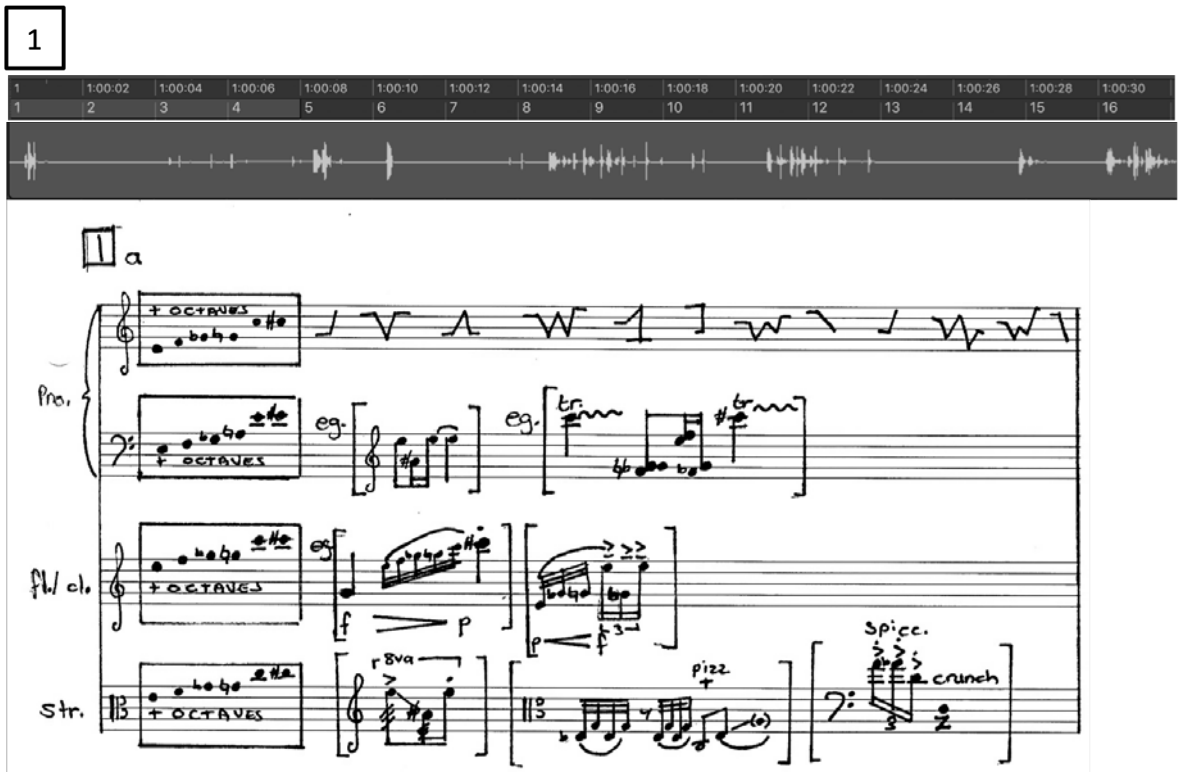

Fig. 5.9 – *At the Node of Ranvier*, score, 'some' parameters given for each section (Section 1a).

The rules of the piece manifested in further allusions to the conceptual framework. Andrews had mentioned how the nervous system sometimes recruits neighbouring cells and 're-programmes' them to carry out tasks they do not typically do. This gave rise to another interaction rule – at any time, any member of the ensemble can creatively solve a problem of routing. During the final rehearsal in the venue, the ensemble discovered that the seating arrangement required by the size and shape of the stage precluded them from being able to give the visual signals they previously introduced to keep the defined chain of transmission in synchronisation with the tape. The ideal solution was that the cellist, rather than the flautist, took on the role of beginning a section ahead of those higher the chain to keep the piece aligned with the track. This followed the rules, since this decision was analogous to a re-programming within the system to account for a break in the signal chain.

The piece follows a programmatic narrative where a hypothetical patient has become injured through his work on a construction site (a common reason for nerve injury cited by Andrews),

and follows his progression through treatment, rehabilitation, setbacks and further surgeries with new scaffolds (see fig. 5.10). The tape part represents sensory impulses being received from the external environment through foley (bouncing ball sounds, drills, dropping a cup of tea), as well as irregular, electronically created pulsing beats intended to describe the internal pain signals that, when the pain is at its worst, take the foreground.

Tape
Sections and Timings:

1 System Working – at leisure, ball tricks – 1min 32sec
2 System Working – at work, drilling – 14sec
3 Accident – 48sec (3a – 3b 6sec, 3b-4 – 42sec)
4 Repair (surgery) – 59sec (53sec to 4a - 4b, 5 sec 4b-5)
5 Recovery – 37sec
6 Training/sport therapy - 20sec
7 New scaffold implant (bridge) – 10sec
8 Improvement – 20sec
9 Set-back – 22sec
10 Stress, disappointment, frustration – 28sec
11 Trying new scaffold (wrap) – 58sec
12 System adapting to new wiring – 1min 12 sec

Fig. 5.10 – *At the Node of Ranvier*, score, tape sections and timings.

The tape is played through a transducer placed on the soundboard inside the piano (see fig. 5.11). This placement worked well with the idea of signals being processed by the brain (the computer as played through the body of the piano), which are internal perceptions of an external world. The distorted quality of the sounds had the effect of suggesting a barrier and an 'outside/inside' distinction.

Microphones are set in front of the performers, and the second transducer within the piano plays this live amplification alongside the tape, conceptualised as a signal feedback loop that travels outward and inward to the brain.

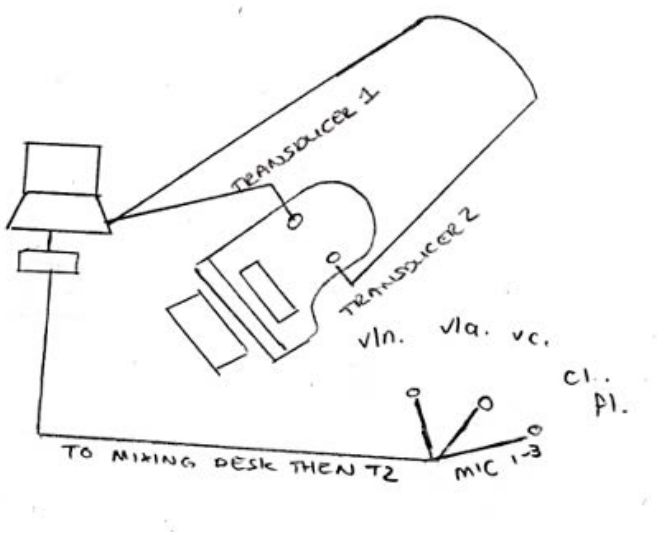

Fig. 5.11 – *At the Node of Ranvier*, score, technical set-up.

The musical material provided is intended to follow the narrative of the tape, such as in the 'drilling' section at 2 (see fig.5.12) where the winds and strings play repetitive, accented rhythms and fluttering pitch movements intended to suggest a sensation of vibration and movement in the hand caused by the working drill. The performers are directed to return to the 'resting state' from the beginning of the piece whenever there is a rest in material from the tape and – in keeping with the rule of order – the performer in the chain above them has returned to this figure.

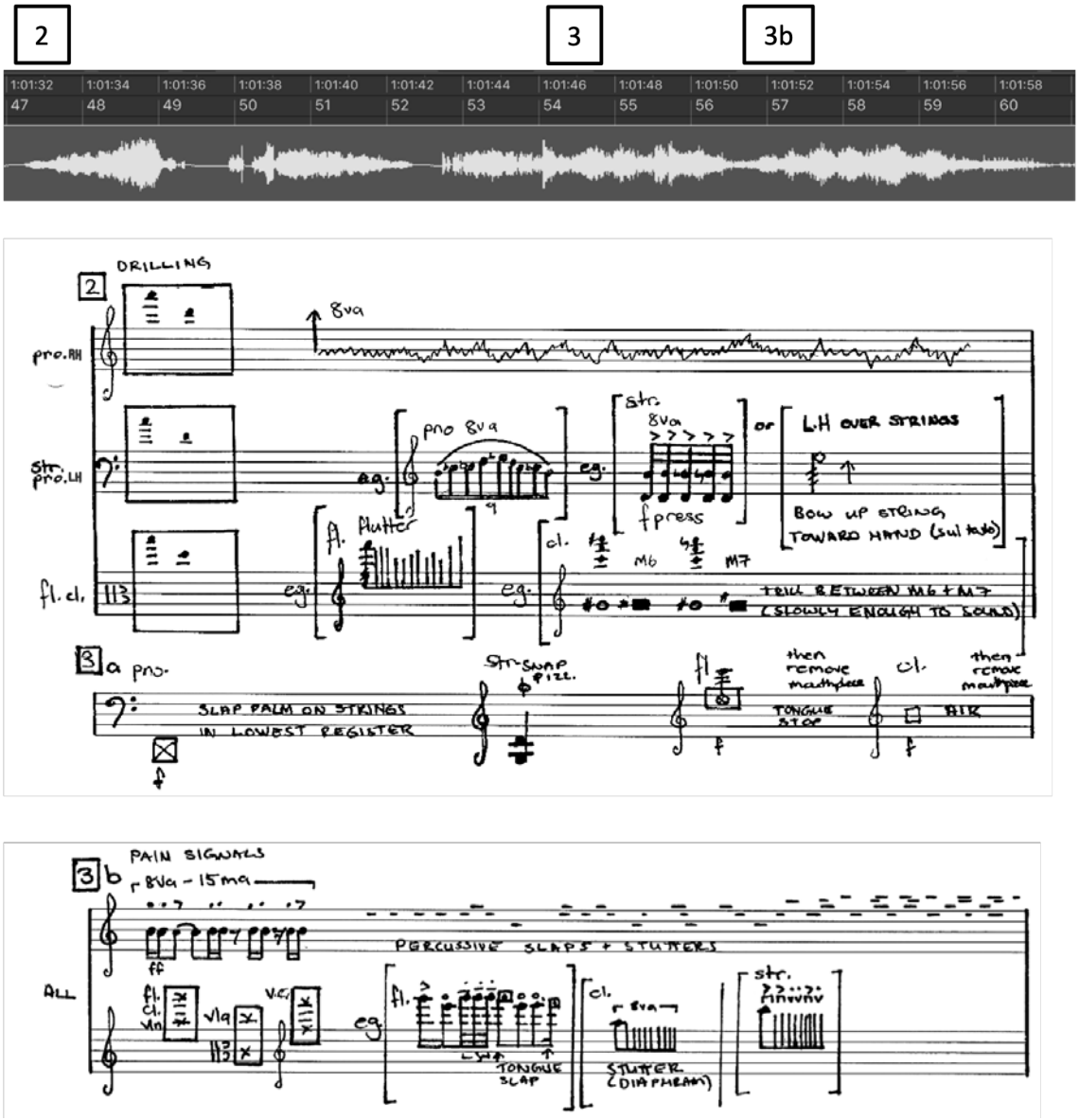

Fig. 5.12 – *At the Node of Ranvier*, score, 'drilling' (section 2-3b).

This piece marked a shift in my practice as it was the first exploration of highly indeterminate material, and interaction-based processes.[61] The decision to map the structural and rule-based parameters of the piece to the concept proved artistically freeing, and this way of approaching the construction of pieces with respect to the conceptual basis was explored further in later

[61] The works in this commentary are discussed in topic groupings, rather than chronological order.

works. This work also marked the first use of technological integrations into the structure and concept of the work, a process that prompted further exploration of technological integration, as discussed in Chapter 6.

COLLABORATIVE SERIES – Professor Mathias Brust

xviii. [U]nusual [m]etals

This audio/visual work emerged from a collaboration during the first lockdown with University of Liverpool Chemist Mathias Brust. Meeting regularly online, Brust and I developed a dialogue that included musical performance as part of the ongoing conversation. This work features the singing bowl and use of camera angles as a response to the theory of wave/particle duality.

Professor Brust and I were interested in building an ongoing collaboration that was conversational in nature, with pieces serving both as landmarks and springboards for future discussions. We approached the series without fixed structure or particular aims in mind, except to create a space within which something might emerge. Following a conversation about wave/particle duality[62] I was struck by how properties of the singing bowl manifested some of these notions to me. The characteristic sound of the instrument is produced by drawing the beater around the outside of the bowl's edge. The sustained tone this technique produces is not able to be reduced to a single instance of contact with the bowl, which I related to the phenomenon we had discussed. As a wave, the additive oscillations produced by the constant friction against the bowl could interfere with one another. But where those were originating from could not be identified as a single point of contact.

To develop the concept further, I used a process of sound design to filter out certain frequencies. Conceptually, both the audio and video components of the piece start from a

[62] One of the underlying principles in Brust's work.

distance. At each iteration, both the camera view and the audio moves 'closer', until it is presenting a 'microscopic view'. The idea is that by homing in, the viewer/listener is 'looking for the source' of the sound, to investigate its properties either as a 'wave' or mass of 'particles'. Throughout each iteration, frequencies are stripped from the sound, moving in an overall downward motion (higher frequencies are stripped, producing a perception that the sound is becoming lower in pitch) with some variation and reintroduction along the way.

When the artefacts of the beater's sound on metal are found - that is, the frequencies audibly related to the wood being scraped across the surface - they are exposed in the mix as if to bring attention to a potential 'particle'-like sound. Following that discovery, the frequencies continue to be stripped until all that is audible is a low frequency (moving between around 65hz – 69 hz), before that, too, stops.[63]

Visually, the piece cycles between four views: top left, top right, bottom left and bottom right (see fig. 5.13). The cycles progress at a higher rate around the bowl as the perspective brings the viewer closer to the bowl. The viewpoint then jumps from those taken with a standard camera lens to photos taken of the singing bowl seen ultra-close via use of a macro camera. Zoom increases on these images on until there is a black screen, suggesting a 'space between the particles', where no further zoom is possible.

[63] Other works that explore the qualities of continuous sounds that do not change pitch include James Tenney's *Having Never Written a Note for Percussion* (1971) and *Composition 1960 #7* (1960) by La Monte Young. While this piece moves progressively down in pitch through frequency filtering, Tenney's *For Ann (rising)* (1969) progressively rises using overlapping sine tones, a related idea explored using different sound design techniques.

Fig. 5.13 – *[U]nusual [m]etals*, visual timeline (arranged top to bottom, left to right).

I was intrigued to find out whether my instinctive association of singing bowl's sound production with ideas around wave/particle duality would be one that Brust would share. Brust expressed to me that he was fascinated by how well this instrument also captured the concept for him, which he experienced as 'the lingering non-located sound as the standing wave of the de-located electrons in the metal, and the scratches and collisions with the beater as manifestations of located particles, collapsed wave functions, perhaps due to imperfections in the metal. I interpreted the electronically filtered overtones as energy levels, perhaps empty orbitals' (Brust & Leeming, 2020). On a musical level, I found the singular focus of each element (acoustic – static pitch; sound design – moving lower in frequency; visual – zooming in) to be artistically interesting to explore, and effective in the way that those singular movements worked together in interplay between mediums.

xix. Surface

This piece was informed by the 'tears of wine' phenomenon.[65] *Dissonance/consonance and intervallic distance are used to suggest various levels of tension (in the scientific sense), and pitch (high/low) to represent travel up or down a metaphorical glass that, together with rhythmic motives, are intended to describe different rising, rolling, and bouncing actions.*

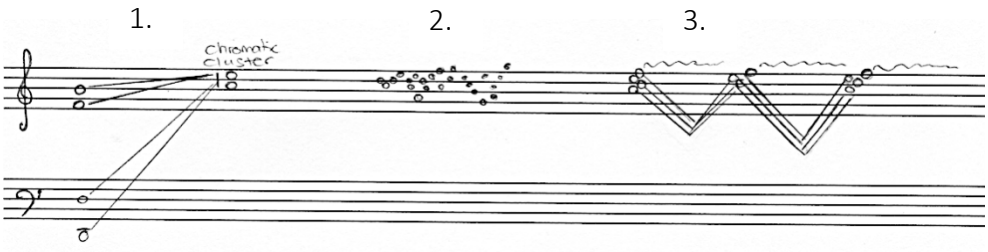

Fig. 5.14 – Early sketch - form and pitch constructs.

Given the limitations on concert performance during the development of this piece in 2020, this version was developed toward a workshop in October which occurred during an ease in restrictions. Due to the limitations on time and instrumentation, I created 'Surface' as an abridged version of a prospective full piece as imagined in the form of Fig 5.14. Early planning as expressed in this figure was mainly followed. In 1., instruments begin with a D minor triad spanning from D2 - 4, then move upward in pitch at different rates such that the intervals become increasingly compressed toward a chromatic cluster around D5. In 2., intervallic distance is incrementally expanded. In 3., one voice remains wavering around F5, whilst the main group of instruments fall, rise, and fall again repetitively in pitch.

[65] The Gibbs-Marangoni effect (Thomson, 1855, pp. 330–335).

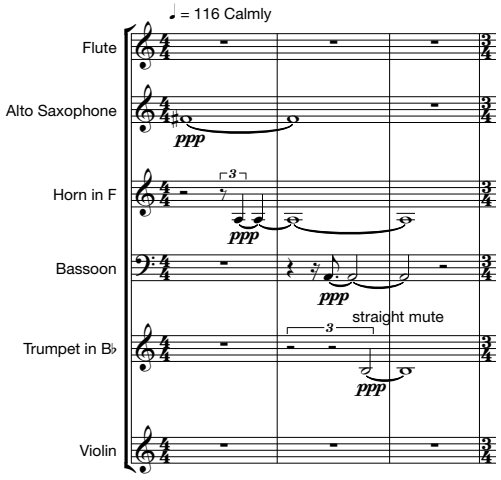

Fig. 5.15 – *Surface,* opening (bars 1-3, transposed score).

The piece opens with an A-D-A-A staggered entry (see fig. 5.15). The F was omitted to increase openness of sound and to avoid grounding within an assumed tonality. Rather than ascending smoothly toward a cluster, the first section lumbers upward in pitch with occasional downward motion – first in semitones, then tones and minor thirds toward letter 'D'. In the proposed full work, this section would have proceeded with upward motion and contracting intervals toward the chromatic cluster. The group of instruments comprising saxophone, horn, bassoon & trumpet conceptually represent a body wine. The gradual increase in harmonic tension represents an increase in tension near the surface of the wine. As this is an abridged version, the 'harmonic tension' here is mild, however it would have developed to become more intense toward the end of the section by a greater use of major sevenths, tritones and minor seconds toward the chromatic cluster.

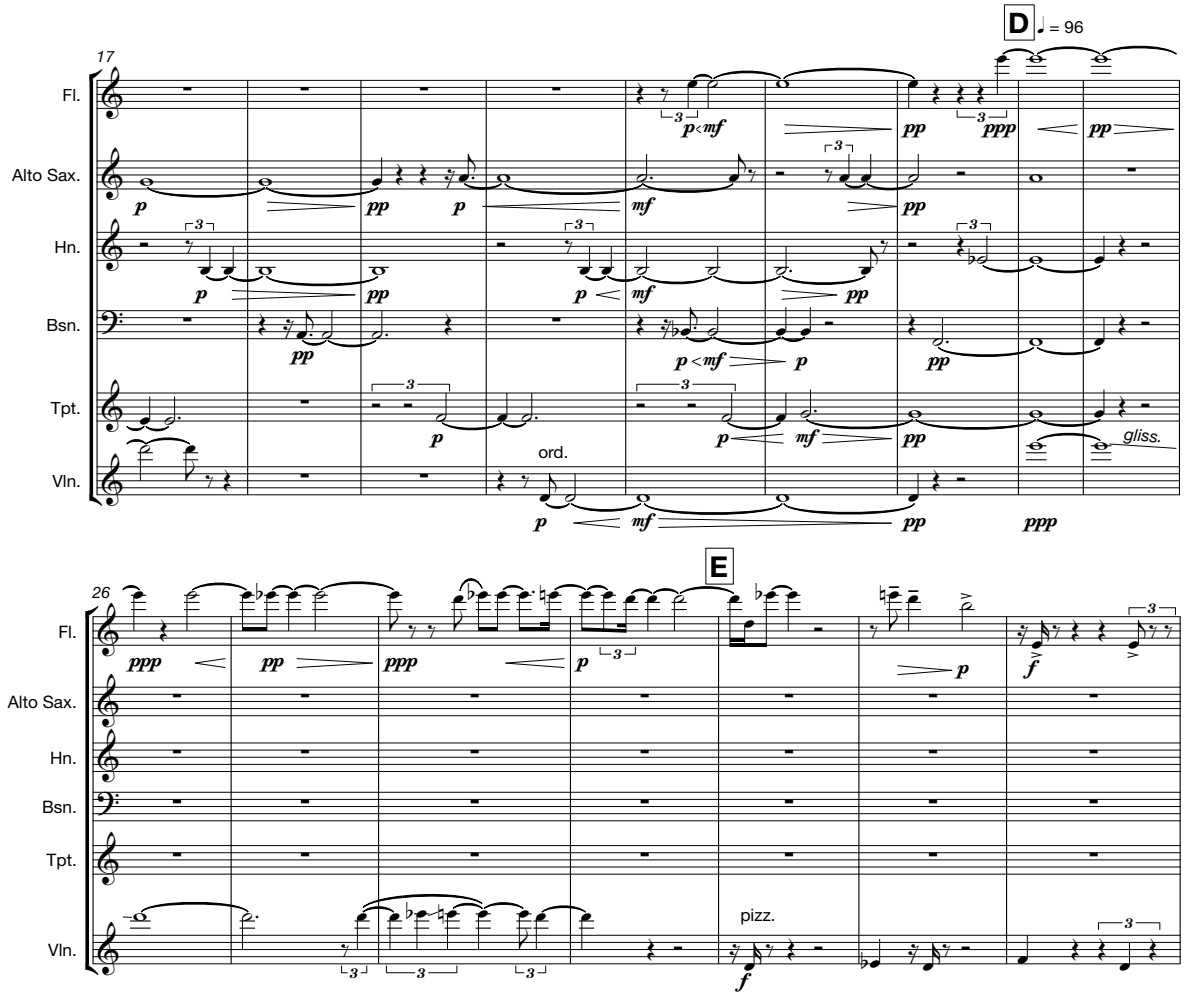

Fig. 5.16 – *Surface,* 'tears' represented by violin and flute (bars 17-32, transposed score).

At 'D', the piece skips ahead to section 2 of the original sketch. The flute and violin here represent the 'tears' (see fig. 5.16). Glissandos are employed to suggest the idea of these 'tears' sliding down the surface of the wine glass, back toward the liquid. Upon contact, 'dripping' and 'rebounding' is described using pizzicato and the sudden intervallic leaps at 'E'. The flute and violin continue acting as these 'tears' throughout the piece, travelling upward and downward in pitch (and sometimes hovering on a sustained tone) to represent this repetitious movement across time. These instruments together retain a higher overall degree of chromatic tension (through use of semitones and unison pitches with wide vibrato) as well as rhythmic tension created by similar rhythms played just out of time with one another ('J' and 'M' in particular – see Fig. 5.17).

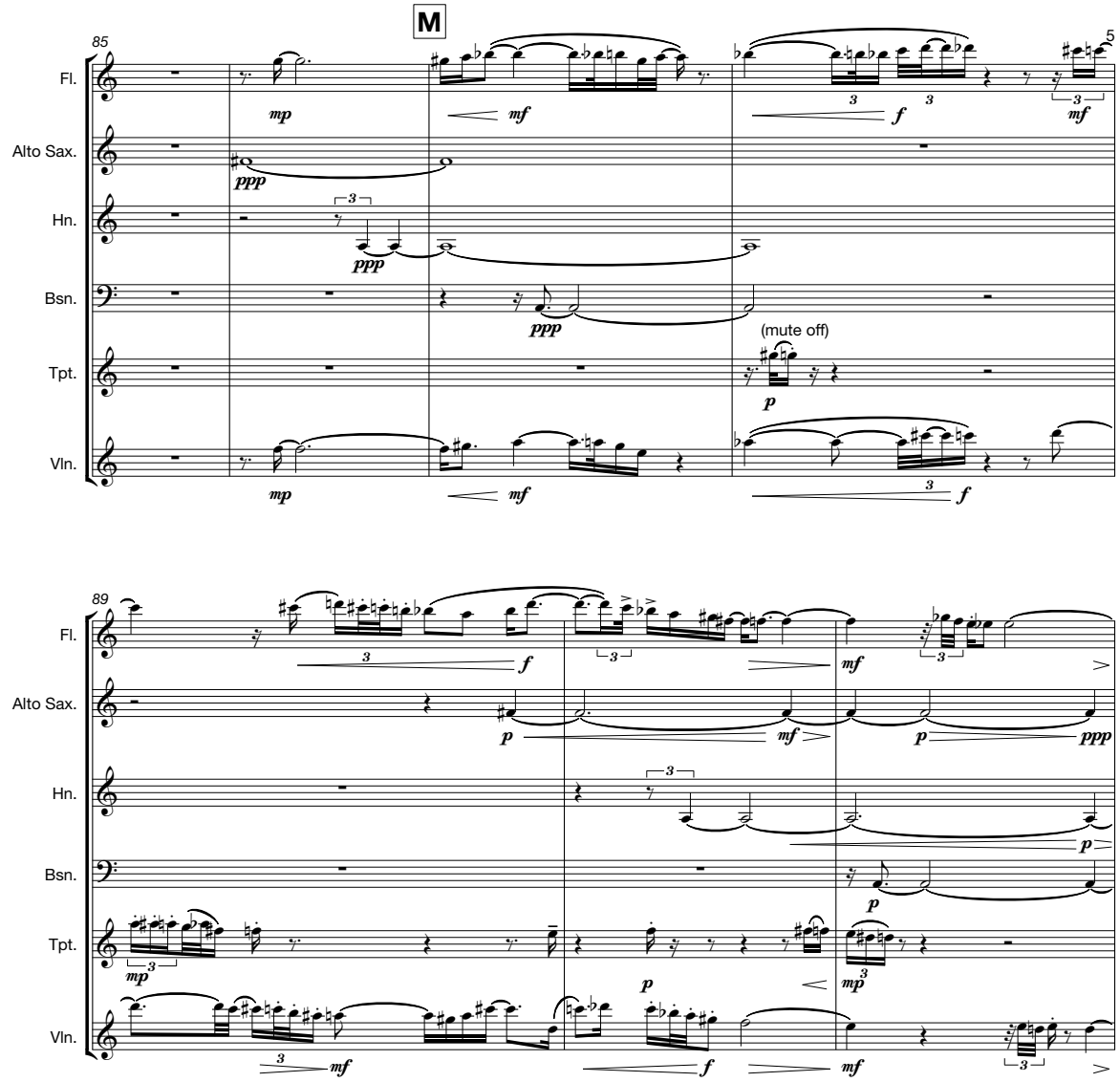

Fig. 5.17 – *Surface,* non-synchronous rhythmic similarity between flute and violin (bars 85-91, transposed score).

Shape No.3 of the original sketch (see Fig. 5.14) begins at 'F' (see Fig. 5.18) with an Fmaj7 chord (E & A in bass). Although the chord itself could be described as relatively consonant, a different type of tension is intended by use of the wide vibrato, particularly between the unison saxophone and horn. The idea was to create tension arising from a sense of instability within a sound that would otherwise feel relatively stable – like a moment of balance which is wobbling, then lost as it tips over. The instruments representing the body of the wine at the surface have reached their highest peak before the combined weight causes a tumbling motion downward.

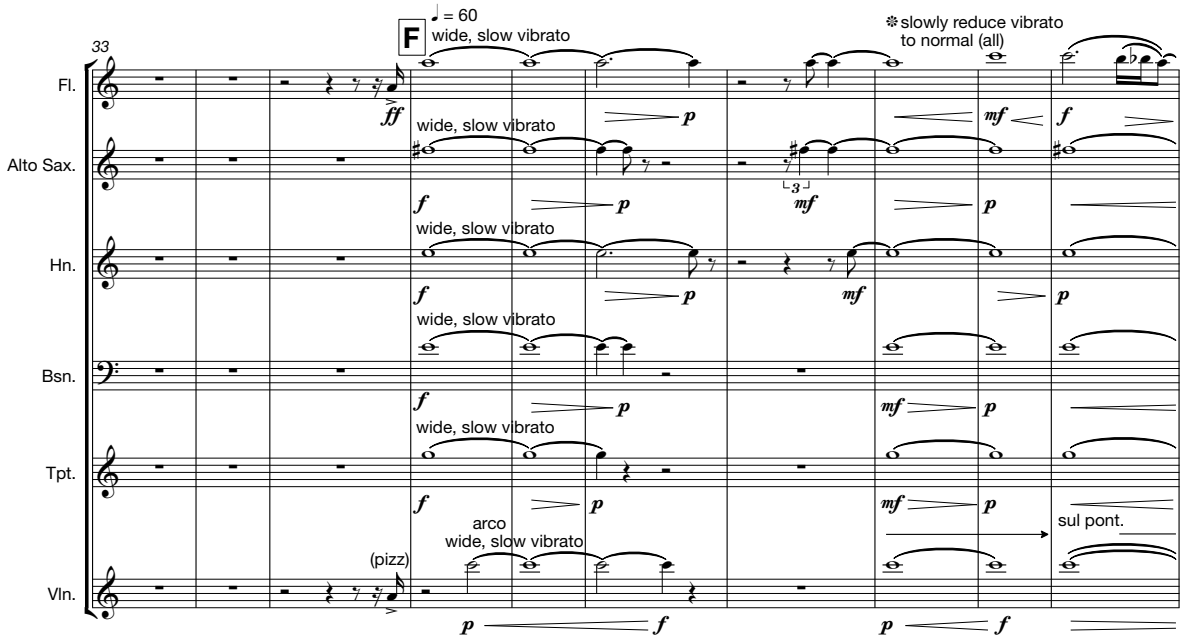

Fig. 5.18 – *Surface,* wide vibrato (bars 33-42, transposed score).

This begins the slow tumbling/rising figure (see Fig. 5.19) that continues through the ensemble until bar 76, and thereafter appears as individual statements until bar 84. In the closing section (bar 85 to the end) the trumpet joins the flute and violin in short movements up and down by semiquavers and semiquaver triplets, for the conceptual reason that, without the weight of the other instruments, it has risen high enough to break the surface and become a 'tear'. These instruments roll down and ricochet in pitch as if against a surface, whilst the remaining instruments return to the stable, open, and consonant state denoting reduced tension as seen at the beginning (see Fig. 5.20).

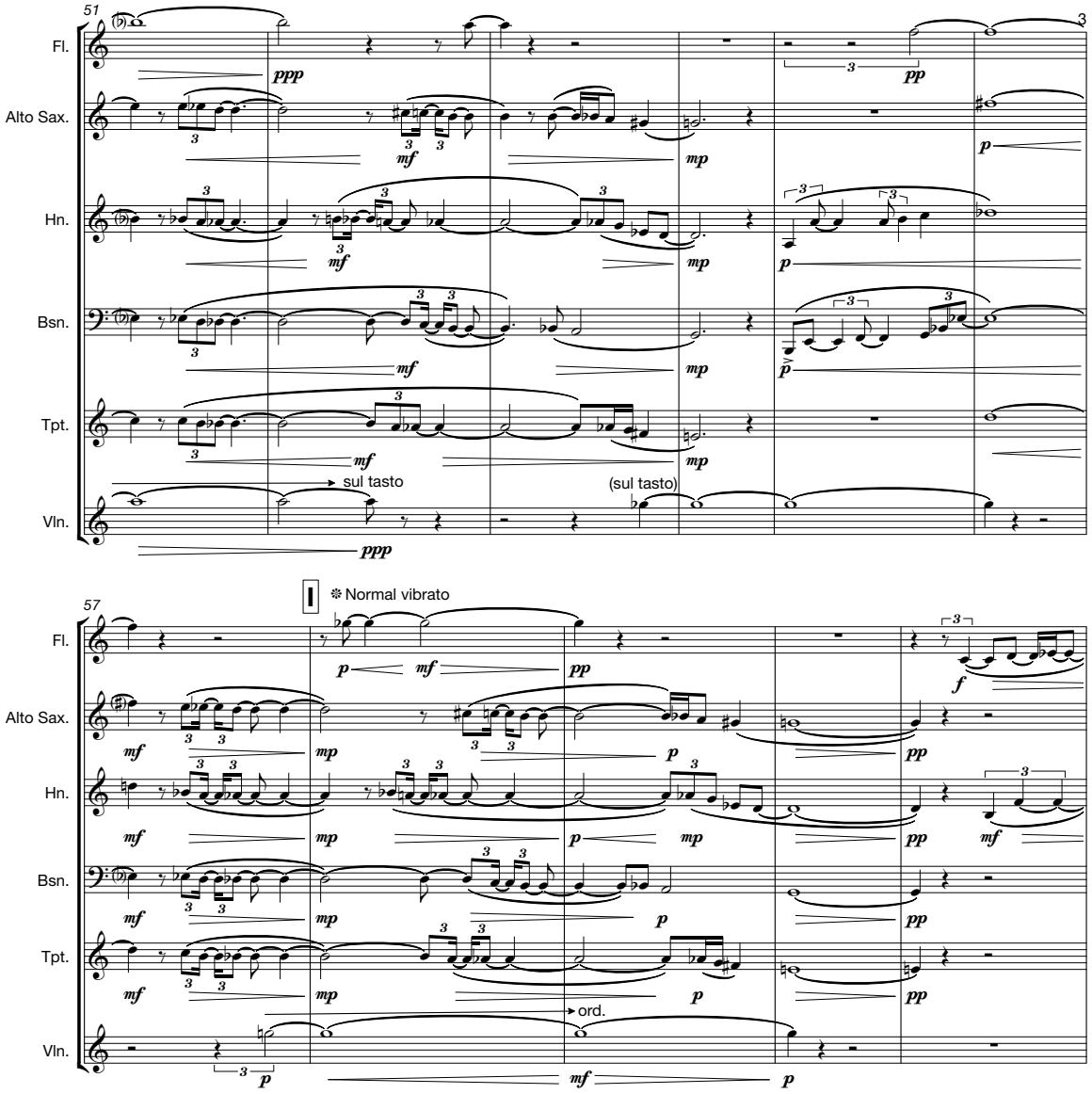

Fig. 5.19 – *Surface,* 'tumbling'/'rising' (bars 51-61, transposed score).

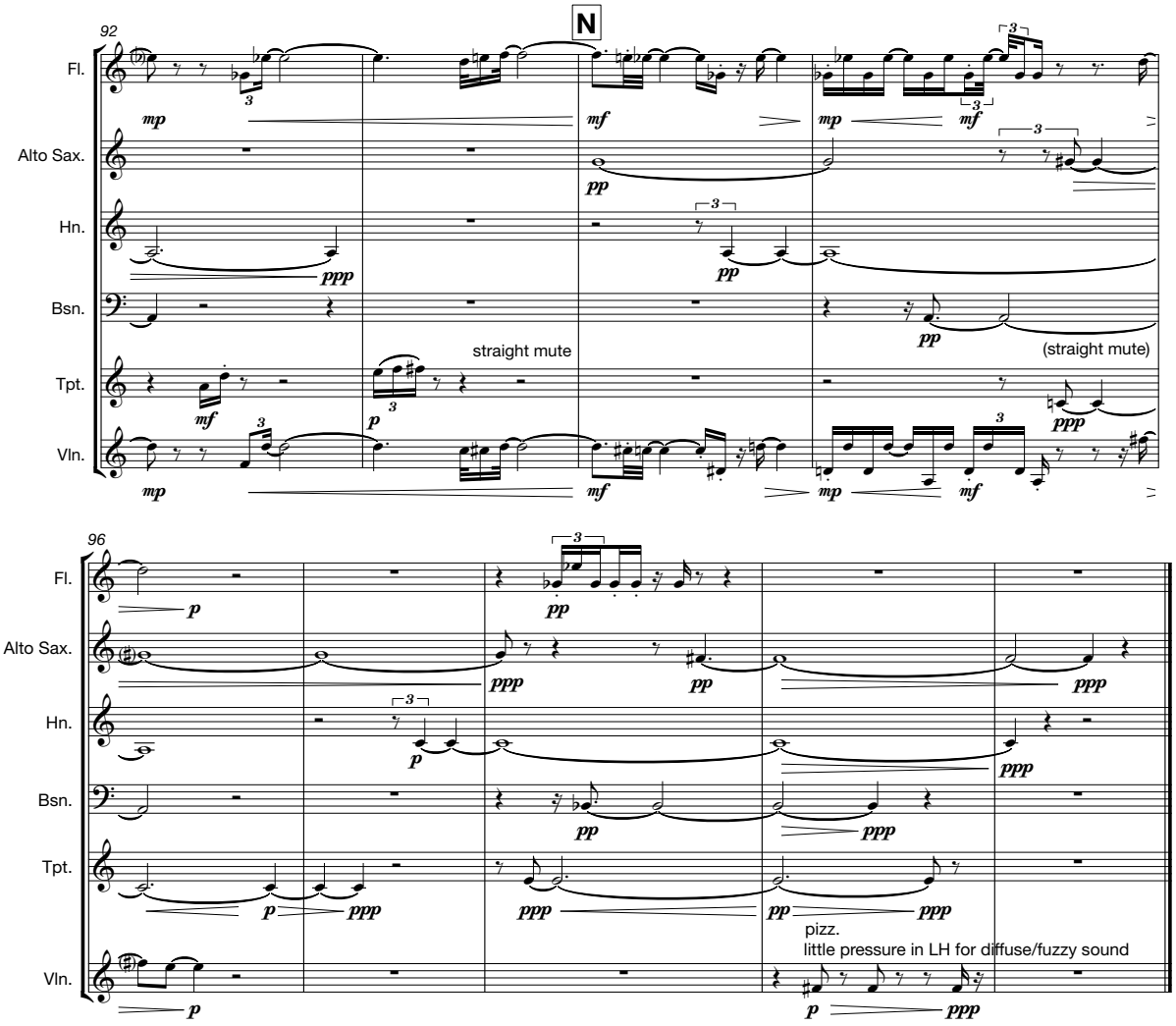

Fig. 5.20 – *Surface,* ricochets, and reduced tension (bars 92–end, transposed score).

The sonority of this uncommon instrumental combination proved aesthetically pleasing, particularly when in consonance at F with wide, slow vibrato and open intervallic spacing.[66] If not for the circumstances that led to this piece (a reimagination of what would have been a larger instrumental work if not for the global pandemic), I would not have made this discovery, which I am now exploring further in a new work. In addition to the suitability of the combined instrumental timbres, I found the rolling movements and tension as explored though the

[66] Although I heard this in person, due to miscommunication the only recording taken during this workshop was a Zoom recording (meeting platform not recording device).

musical meanings of those terms to be effective and evocative of the phenomena I had studied whilst writing the piece.

xx. Waterwheel

This work explores concepts from Brust's current research musically through conversion of energy (literal and conceptual), relative levels of determinism in scoring, and distinct types of ensemble interaction.

Professor Brust's research explores ways to create chemical energy conversion similar to the ATP process in living organisms. In this piece, electrical energy is converted into mechanical energy using different vibrating devices placed on percussion instruments, a technique used as the central analogy.[67] The movements are drawn from the range of problems Brust has been facing in his models, using ensemble interaction to explore musical structures as analogies to these, as well as levels of deterministic versus indeterminate material to explore the impact of degrees and types of freedom within the system. Each movement represents one of these problems.[68]

Mvt.1 – 'Potential'

> Initially, they are almost completely isolated from each other, and the emulsion has a lot of potential. (Brust, in *Waterwheel*, 2021)

[67] This technique was developed by composer Alberto Posadas and Ensemble Recherche percussionist Christian Dierstein and is featured in the composer's work *Trayectorias* (2018).

[68] As described by Brust in the score: 'Each of the five sections in this composition refers to one stage in the development of a liquid mixture that is capable of converting energy, much like a waterwheel or a battery. The mixture, a so-called emulsion, consists of many tiny water droplets suspended in chloroform. These droplets contain chemicals that would strongly react with each other if the droplets could come together' (Brust, in *Waterwheel*, 2021).

The piece begins with electric toothbrushes placed against the timpani membrane to induce vibration. Whilst the only real conversion of energy is this conversion of electrical energy to mechanical energy (which is later used to induce further mechanical movement of objects placed on the head of the timpani), conceptually, the energy produced by the percussionist through this method is the source of all energy within the system (ensemble). In the first movement, a feeling of pent-up energy that is waiting to be released is described using short rhythmic durations interspersed with silence, pressurised techniques in the strings and winds and a general lack of sustained movement in pitch. There are also additional performative actions, such as the instruction to 'build air pressure in mouth' before release (see fig. 5.21).[69]

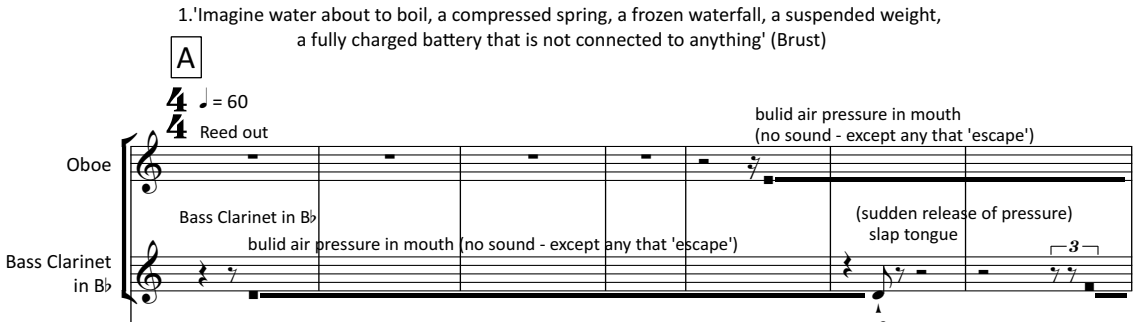

Fig. 5.21 – *Waterwheel*, oboe, and bass clarinet, building of pressure in mouth toward release (bars 1-7).

The notation style is deterministic and fixed, with no aleatoric, improvisatory or (atypical) performer-directed options available. The fixed scoring is used as a further analogy to the problem described by Brust that resulted in this type of failure: not enough freedom within the system.

Mvt.2 – Battery in Water

[69] This action should be visible, such as through strained facial muscles.

> *The reaction*[70] *now proceeds, and the energy stored in the system is released in an uncontrolled manner, just like it happens with a* ***battery in water***. (Brust, in *Waterwheel*, 2021)

The 'problem' explored musically in movement 2 is not a of lack of flow, but too much flow that happens too suddenly. In this opposite extreme, the greater number of performance interpretations similarly lead to a lack of flow, albeit one that sounds and acts very differently. Here we see the introduction of significant lengths of sustain (woodwind entry at bar 29 – see fig. 5.22), and progressive movement in pitch (strings in bar 29 – see Fig. 5.22), however there is no sympathetic movement *between* the instruments, nor any regularity in movement emerging. Despite the ensemble then being directed to follow the percussion as it rises and falls in intensity from letter H, the available material can only result in short bursts of sound, or in a more 'chaotic' sounding timbre that sits somewhere closer to noise than to pitch, the latter of which is the result of idealised 'flow'.

[70] The reaction 'can be achieved by adding small gold particles, which serve as shuttles for the chemicals so that they can move between the droplets' (Brust, in *Waterwheel* 2021).

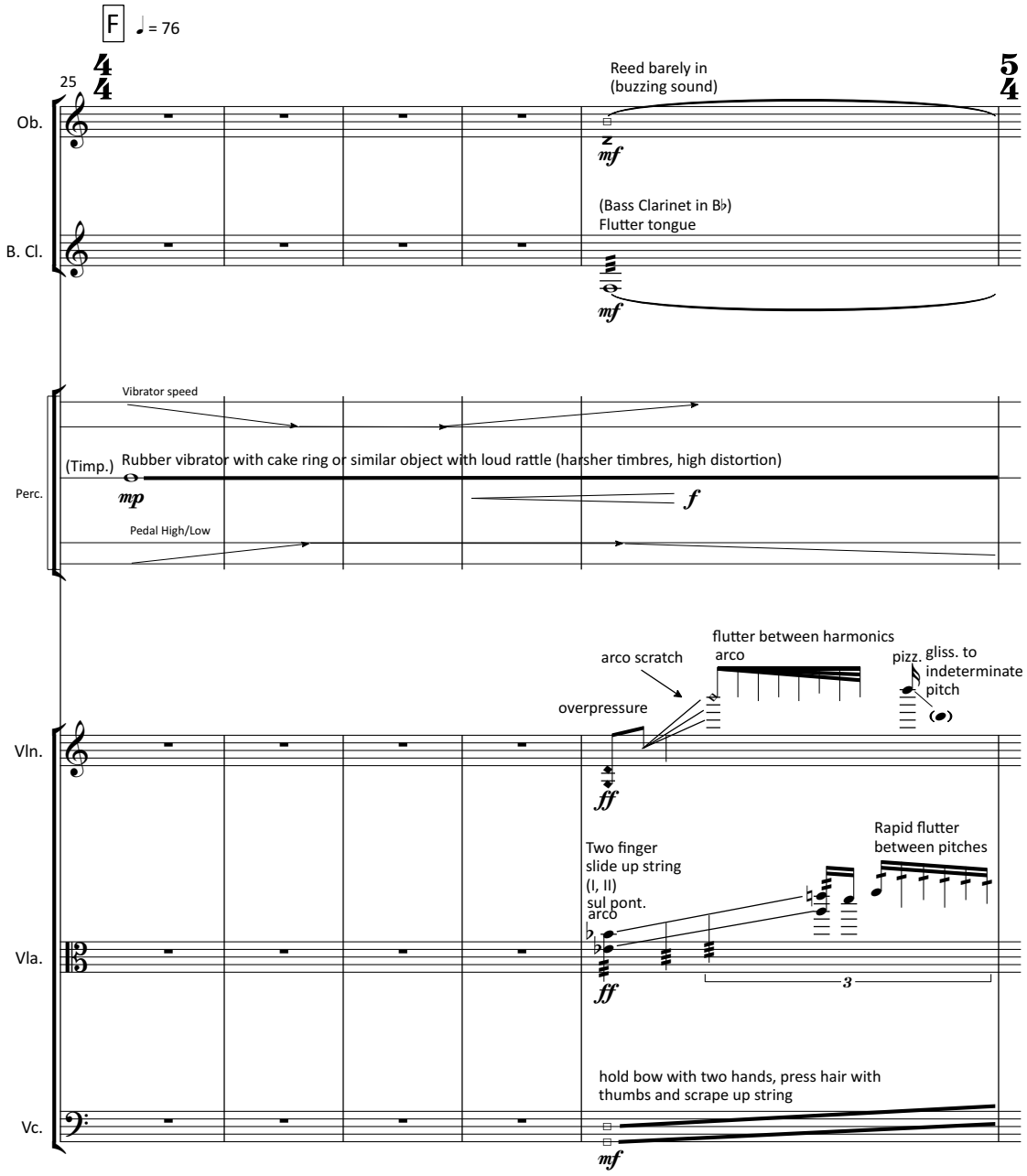

Fig. 5.22 – *Waterwheel*, emergence of sustain in woodwinds, pitch movement in strings (bars 25-29).

The less definite scoring suggests many more interpretations than the notation style of movement 1, conceptually describing a system with more (here described as 'too much') freedom. I was interested in this juxtaposition as a mirror to the idea that a similar type of 'chaos' in sound can result from both highly deterministic and highly aleatoric scoring (Xenakis,

1955), however, here I was not aiming to produce a similar type of sound but a similar musical outcome (a lack of what has been defined above as 'flow').

Mvt.3 – Emergence of regulation

> ….The task [is] to control these reactions and to salvage some of the energy they release. When this happens, **regulation** emerges (Mvt. 3), and we are beginning to convert one form of energy into another. (Brust, in *Waterwheel*, 2021)

In movement 3, a greater level of determinacy is reintroduced and there is a focus on the production of sustained pitch material. Conceptually, parameters for the control of the 'reactions' have been found, allowing this to occur in contrast to movement 1. Musically, this is presented by a movement toward more stable pitch-based sounds with longer sustain, and greater capacity for movement in pitch in a progressive manner, through both moderate glissandos (in intervallic distance and duration), and movement in trills and vibrato (not the large leaps or fast and large movement in range of the previous movement) (see fig. 5.23).

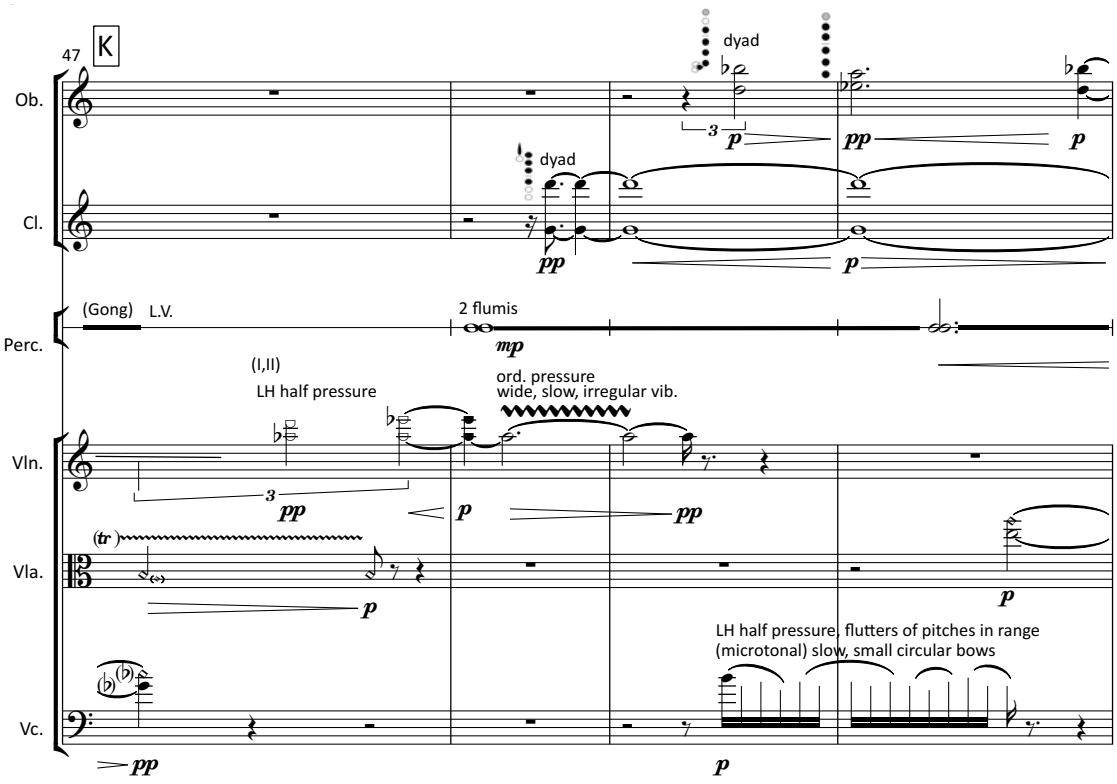

Fig. 5.23 – *Waterwheel*, score, moderate movement in pitch and increase in regulated sustain (bars 47-50).

Mvt. 4 – Sieve

> A main problem has been the leakiness of the system. Imagine a waterwheel with many holes in it. Every segment of it is in reality a **sieve**. It would hardly turn, and the energy of the water flow would be lost like in a rain shower. (Brust, in *Waterwheel*, 2021)

In movement 4, 'rise, sustain, fall' figures are described in boxed notation and graphically indicated thereafter (see fig. 5.24). This reintroduction of freedom within the notational (and thereby performance) expression describes a further problem with wide possibility for freedom even within a system with emerging regulation. The freedom has enabled the beginnings of what might eventually produce 'flow', but it is also responsible for huge loss in the system. Musically, this is represented by the 'falling' figures, and the silences between. In the section from P to Q (see figs. 5.24 & 5.25) these gestures are arranged in time such that they almost swell and fall together, however since the instruments are slightly out of time, a unison swell is not achieved.

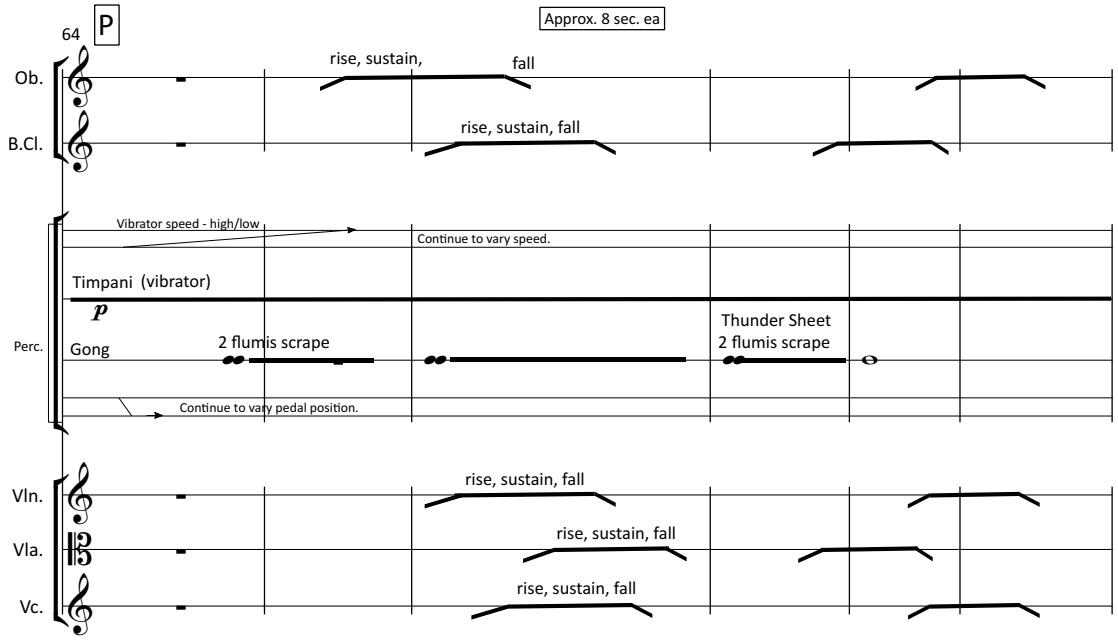

Fig. 5.24 – *Waterwheel*, score, 'rise, sustain, fall' (bars 64-69).

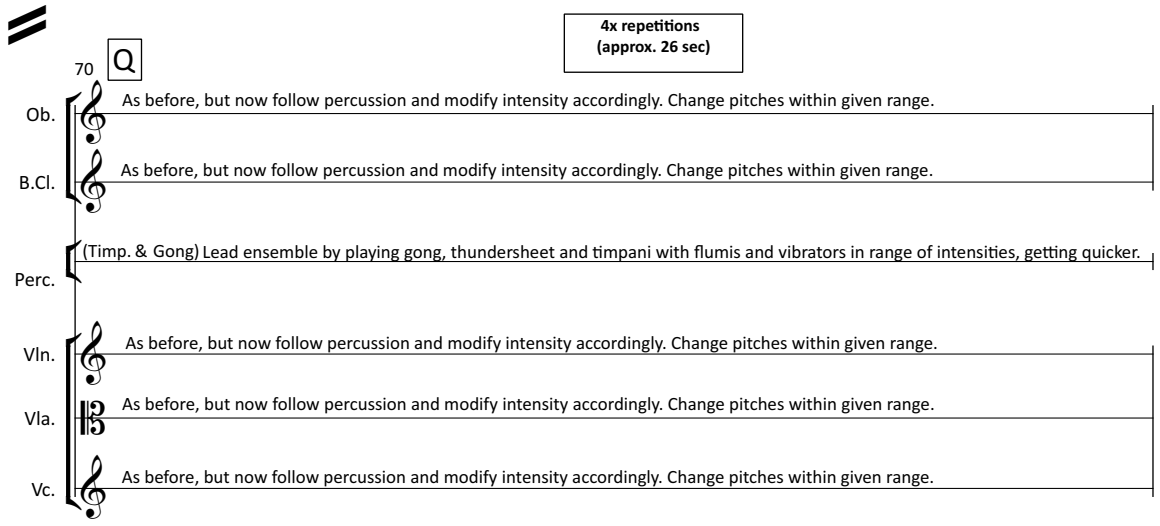

Fig. 5.25 – *Waterwheel*, score, following percussion, (bar 70).

Mvt. 5 – Waterwheel

> Our aim has been to minimise this loss by allowing the chemicals to react only in one of many possible ways…[71] which could be chemical, electrical or mechanical, as in a **waterwheel**. (Brust, in *Waterwheel*, 2021)

Movement 5 finally arrives at a 'working' system. The energy created by the vibrator on the timpani begins to rise and fall in a pattern, if a lopsided one (expressed by the recurring uneven pulse in the change from 2/4 to 7/8 throughout). The strings emerge into pitch from the airy, noise-based sound of bowed bridges and begin to swell and subside almost in synchronisation with each other, intended suggest there is enough order to commence a transfer of energy capable of sustaining a cyclic motion between them. By figure X (see fig. 5.26), the woodwinds have settled together in time, and this further indicates a system of 'flow' between the ensemble. Beginning with the timpani, the 'energy' being 'converted' by the ensemble can 'produce motion' that (as set out in the concept) induces sound waves. The ensemble is finally

[71] The quote continues, 'which would lead to our ability to harvest the chemical energy and carry out some form of work'.

able to ‘demonstrate’ this by the production of a sustained fourth (chosen for its association with a stable quality).

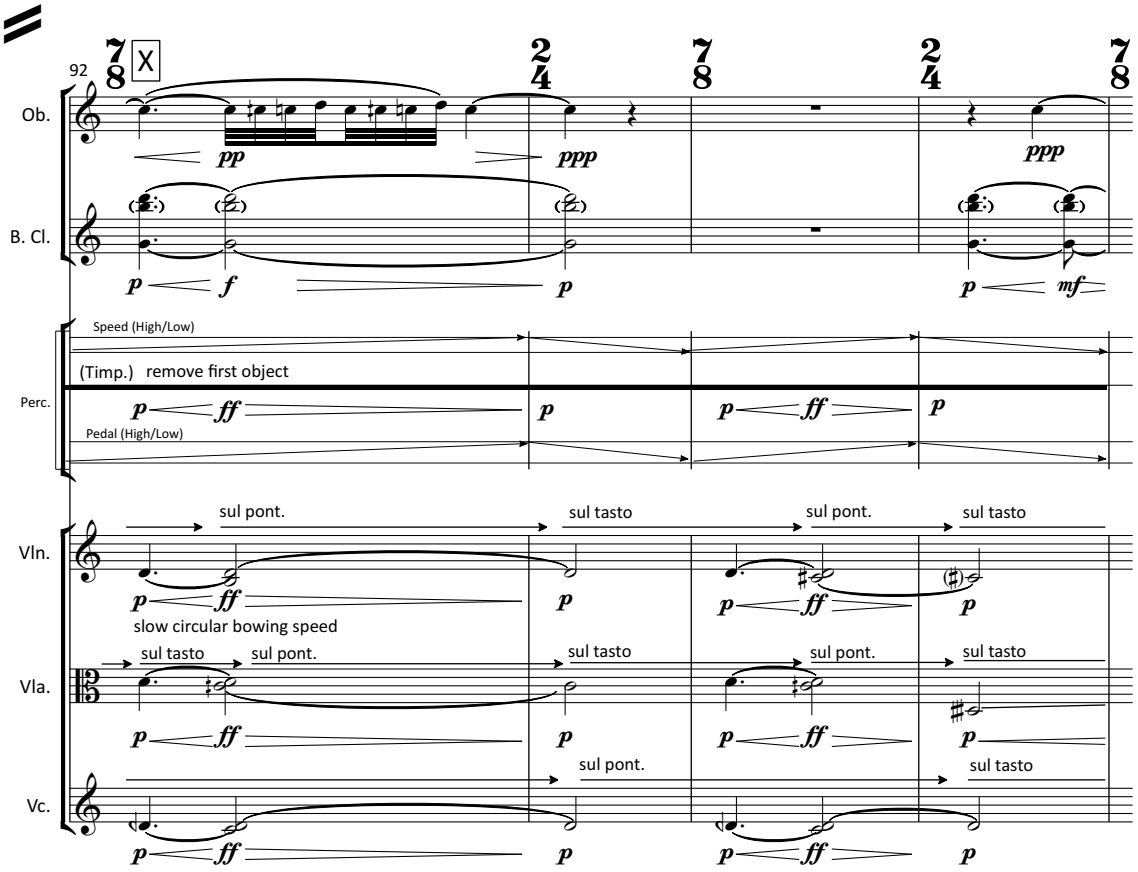

Fig. 5.26 – *Waterwheel*, score, synchronicity in swell (bars 92-95).

Mvt 6 – Equilibrium

> Finally, all chemicals have reacted and the system gradually comes to rest at **equilibrium**. (Brust, in *Waterwheel*, 2021)

Movement 6 takes the piece from a state of energy production toward dissipation of all energy in the system by way of Brownian motion, modelled through ensemble interaction. All performers begin with quick movements in pitch and/or rhythm such as smooth (non-accented) trills and tremolos (see fig. 5.27), then gradually increase the separation in time between these actions until only single attacks are heard, before they also peter out. During this overall movement toward silence, changes in pitch and level of separation are made

primarily by responding to a change by the performer to the person's left or right, with the additional option to start one of these chains of change.[72] The system gradually comes to rest, with occasional bursts of remaining 'energy' heard in the final attacks made by the woodwinds at figure FF (see fig. 5.28).

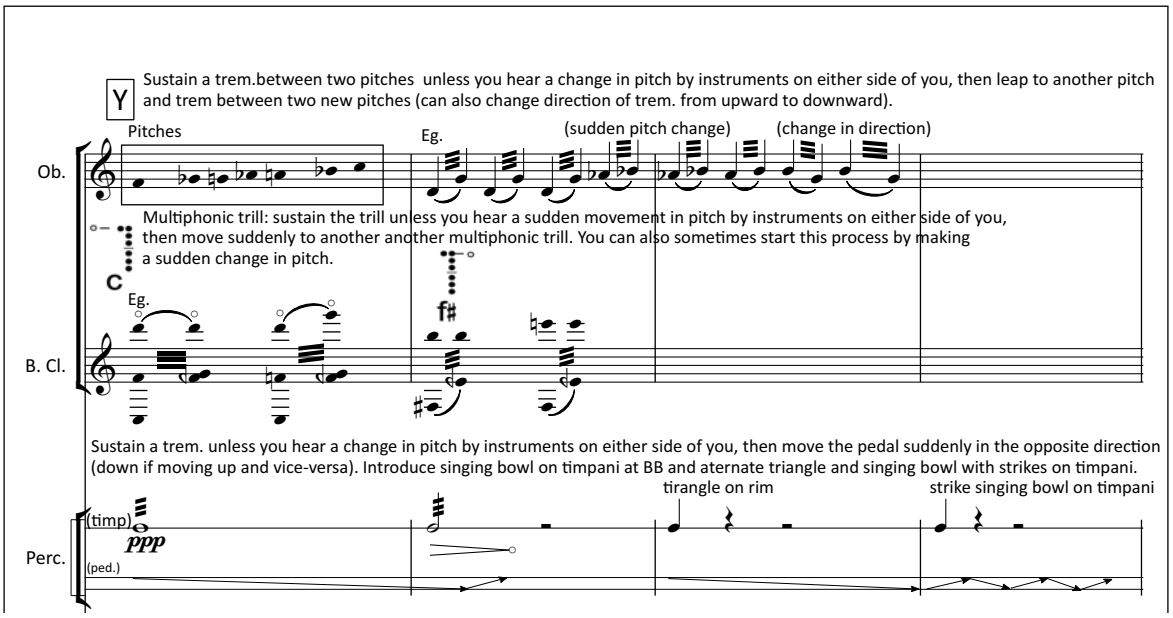

Fig. 5.27 – *Waterwheel*, oboe, bass clarinet and percussion, boxed notation giving performance options (letter Y).

[72] Richard Barrett's *Codex* (2000–) follows a similar idea in presenting a range of improvisatory settings together with given directions, sometimes in notation and other times as text. *Codex V* (2007) includes a high degree of text-based material in combination with information on staves. The sections of *Waterwheel* explore different degrees of each, concluding with a text-based score laid over empty staves. This movement invites the performers to make performance decisions based on listening to and interacting with other ensemble members, such as in Christian Wolff's *Burdocks Number IX* (2002).

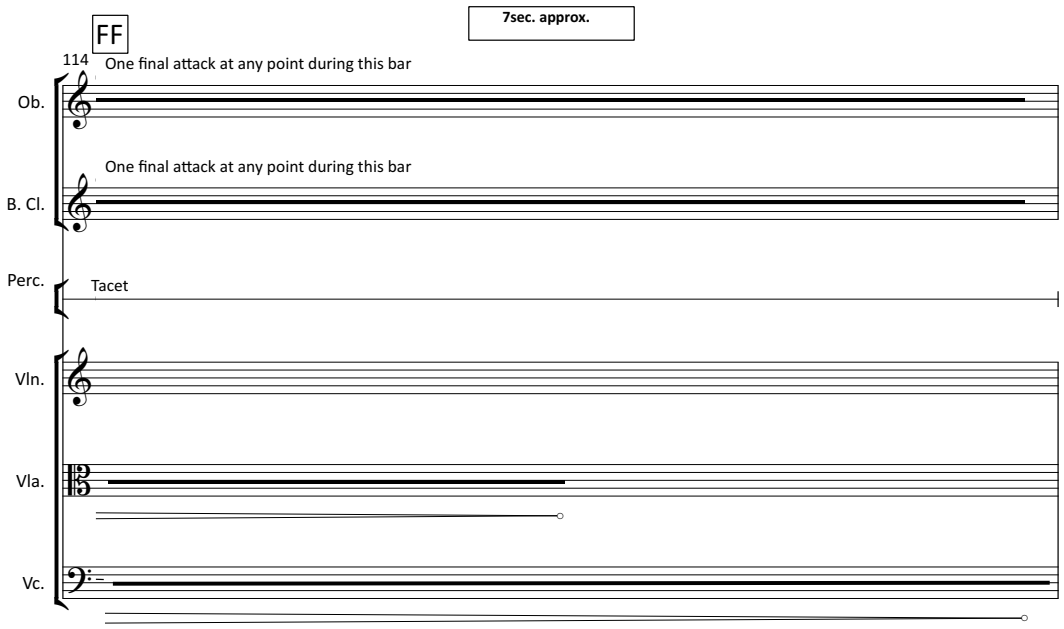

Fig. 5.28 – *Waterwheel*, score, final attack in woodwinds (bar 114).

I found the integration of the electrical devices to be successful in not only exploring a direct instance of energy conversion within a wider conceptual framing, but also as a central feature of the piece from which further decisions were made. By using these electronic devices and percussion as a lead instrument for the duration of the piece, it produced a sense of cohesion, with each movement providing a different opportunity to explore the further possibilities of such a configuration. From a conceptual perspective, Brust commented that he experienced the movements as sonic representations of the subject matter we were exploring, and at many times in our exchanges detailing exactly how he 'heard' the phenomena acoustically. Whilst this was not an intention in the process of composition[73] it reflected a communication (even just between the two of us) that had gone well, so I took this information as evidence that we were able to develop a type of shared language.

[73] (That he or anyone could 'hear' the processes I was setting musically through my own instinctive and musically driven choices).

COLLABORATIONS – Health Researchers

xxi. Hub

'Hub' presents four passages, the discrete musical parameters for which are increasingly adopted by each other through a process of cross-integration.

In 2018 I was commissioned to write a piece for Connected Health Cities (CHC),[74] a knowledge-exchange project linking health data projects across four regions in the North of England. I constructed a form and process for the work informed by the CHC's method as described to me by Dr Amanda Lamb.

The first section presents musical content constructed for each of the areas from specific parameters assigned to that geographical region (see fig. 5.29).[75] Some motivic development of the material occurs during the first statement of each area to represent the learning and development occurring within that health project. In the second movement, the parameters from one other musical area are adopted (e.g., the pitches of Area 2 can now be heard in Area 1's section) to represent regions being influenced by knowledge exchange facilitated by the Hub. Further musical development is used to represent the idea of 'learning outcomes being put straight back into practice' as a crucial point of the CHC project. A second cycle of integration and subsequent development occurs in Movement 3 (Areas 1&3 and 2&4 now exchange parameters).[76] The concluding section completes the integration of parameters whilst providing side-by side comparisons of the material both pre- and post-synthesis. This

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[74] 'Connected Health Cities was a government-funded programme that used information and technology to improve health and social care services for patients across the North of England…The Hub deliver[ed] a number of cross-cutting projects that unite experts from across the North for patient benefit.' (Connected Health Cities, n.d.)

[75] The parameters were not chosen for reasons related to any characterisation of areas but rather to be distinctive from one another, e.g., intervals were considered when distributing pitches such that no two areas had identical interval sets.

[76] Therefore, each Area now has the option to use parameters for 3 Areas of a total 4.

was informed by the idea of the Hub 'reviewing processes and analysing outcomes' and the snapshots of previously heard material are presented to 'frame the successes' of each region. Throughout, each area maintains its core identity by only adopting parameters of another section rather than using quotation or transforming motivic gestures.

Musical Parameters associated with the Areas:

	Area 1 (North West Coast 'NWC')	Area 2 (Greater Manchester 'GM')	Area 3 (North East & North Cumbria 'NENC')	Area 4 (Connected Yorkshire)
Technique	Air Tones	Bisbigliando	Flutter Tongue (not used)	Double-tonguing
Dynamic	fp	ppp	p < f	fff
Ensemble Interaction	Independent Development (any type)	Rhythmic augmentation	Canon	Unison Rhythm
Rhythm	Quaver triplet	Breve	Feathered beam over bar from demisemiquavers to quavers	Quaver, dotted quaver
Pitch	C, B♭, F	E♭, A, G	E, A♭, D♭	D, G♭, B
Interval	2nd, 4th, 5th	Aug 4th, 2nd, 3rd	Dim 4th 5th, Aug 2nd	Dim 5th, Aug 3rd, 3rd
Tempo	Crotchet = 92	Crotchet = 50 (should this be quaver = 100?)	Crotchet = 84	Crotchet = 132
Time Signatures	7/8, 3/4, 4/8	7/8	5/4	4/4

Fig. 5.29 – Table of musical parameters associated with each geographical region.

The structure and process followed in this piece provided another way of thinking about the integration and development of different musical combinations. Since the intention was to mirror research projects that retained an individual identity whilst sharing new knowledge and practice, the material was integrated, but not homogenised.

xxii. Dawn, on the Morning After the Storm

This piece was the result of a series of discussions with members of the ISARIC4C[77] *pandemic consortium. I met with each of the seven researcher/performers online and asked questions about both their professional and music history, role in the consortium, and what effect that work had on their musical lives. These responses informed the construction of the work that was premiered online together with the mini-documentary* In Conversation *detailing the researcher/performers' experiences of both the pandemic and this project.*

The project began during the initial lockdown period of 2020 and included seven doctors and researchers from the ISARIC4C consortium. The most common reason given for wanting to be part of this project was to reclaim a space for music-making during a period in which many expressed they had little to no respite, and had lost access to their typical music-making activities. Practical considerations played a large factor in the initial plan and design for the piece. These included:

- Highland bagpipes are limited to seven notes within the A mixolydian mode.
- The bagpipes are not in concert pitch.
- Rehearsal time could not be guaranteed.
- The performers would need to record to a click.
- The performers would not be able to hear each other, or tune to each other.
- Some performers had recording devices, others used their phones.
- No performers had a studio space, all locations sounded quite different.
- There was a wide range of instrumental experience, and performers were playing a second instrument.

With these parameters in mind, I decided on a structure for the work that I felt addressed the key points of the discussions about their experiences. The responses from the doctors and

[77] ISARIC4C is recognised as a sovereign covid-19 research programme to meet urgent public health needs for the UK. It is a collaboration of over 200 scientists from 11 institutions and NHS teams from 350 hospitals. Outputs from the project have informed the UK's response to the current pandemic, based on data and biological samples from patients in hospitals across the UK, and is one of the largest covid-19 projects in the world. (ISARIC, n.d.)

researchers were arranged into themes which were then related to specific instrumental groups so that no performer would be required to play for the duration of the piece and rehearsal time could be managed. The decision to keep the content largely and straightforwardly modal/tonal[78] was taken firstly because it was in keeping with the link to Scottish folk music that many of the performers highlighted in their performance backgrounds (and of course was playing to type with the bagpipes) and secondly due considerations around limited rehearsal time and the need to retune all instruments to accommodate the bagpipes.

The lyrics of the piece were written following the discussions,[79] many of which highlighted an emerging understanding of the pandemic occurring in waves, from which the metaphor to the tides was developed in the lyrics. The sea-based imagery depicted in the lyrics also influenced the decision to use compound time in many sections. The visuals that accompanied the online premiere, including images and transitions were also chosen with respect to this metaphor and the content of each movement.

This piece was both emotionally challenging to write and a cathartic experience.[80] Since every element of the piece (instrumentation, tuning, harmony, style, narrative structure, emotions explored) were informed by the experiences and histories of the doctors and researchers I interviewed, the experience felt very personal, and there was an accompanying sense of responsibility in getting it 'right'. The accompanying mini documentary that followed, *In Conversation,* provided insight into the experiences that shaped the piece, something that I felt was not only successful in framing the piece but in some ways, I have come to view as part of the work itself. The collaboration and format both prompted me to explore further

[78] Scottish folk music written for the highland bagpipes commonly employs a mix of D major and/or A mixolydian. Other options are B minor and the occasionally used E Dorian.

[79] I chose to write the lyrics for two reasons: firstly, because that is my general preference, and secondly due to the aims of project to create a piece in response to the interviews, a lyricist would have needed to be involved in the project from the beginning.

[80] The first response I had from a fellow composer after the online premiere was 'I needed that.' Which I felt summed up the experience.

questions around who we as composers write for, and how we share both the works and our processes.

CHAPTER 6

COMPOSITIONAL STRATEGIES – Iterative & Generative

xxiii. Iterative: The Aubergine Soup Tourine Project

What is at issue, rather, are the possibilities for the iterative reconfiguring of the materiality of human, nonhuman, cyborgian, and other such forms (Barad, 2007, p. 178).

This chapter explores the development of socio-philosophical discussions around the meaning and role of science in the current era as well as how those considerations influenced my practice.

Several questions had developed during the previous research that I sought to address more directly during this period. These frequently stemmed from debates concerning the notion of reality, both in a scientific sense (following discoveries in quantum theory) and in philosophical discourse. Working on a project that engages with science within an artistic discipline exposed me to a lingering tension between the fields I had not previously been attuned to, and this apparent conflict that first led me to explore philosophical debates that surrounded it. Following a period of deepened division between the sciences and arts in the postmodern era, Karen Barad's *Meeting the Universe Halfway* (2007) provided a new philosophical framework through which to negotiate ideas of reality that also appeared to bridge these discussions within academic philosophy with modern science. Since Barad's considerations were developed within the same cultural space that I had been working in, and considered many of the same questions, reading this seminal text impacted the way I conceptualised aspects of my practice during this period.[81] Further, the enhanced role of performer choice and

[81] I am here focusing on Barad (2007) given the centrality of this work, however it includes the discussions mentioned within her text more widely, such as Haraway's posthumanism. These ideas provided a new lens through which to view areas of my practice such as the augmented instruments and performance methodology of At the Node of Ranvier (that could be said to be both 'cyborgian' and

indeterminacy in my work during this time had led to deeper consideration on the material agencies of instrument/performer/environment combinations in conjunction with scores and the composer/ensemble workshopping process. Barad's intra-action theory[82] provided an additional lens through which to explore these issues within my research. Related questions, such as the introduction and agency of technological developments, also led me to consider Haraway's posthumanism[83] and the wider discourse around human/machine hybridity in the digital age.

My own continued interest in quantum theory merged with the previously mentioned considerations to create the *Aubergine Soup Tourine* Project. Chosen for the multiple meanings the title can infer[84] as well as its playful quality, the name of the project is itself the beginning of an intended 'diffractive' pattern of meaning of the phenomenon[85] that is the project.

'intra-active'); the iterative interaction of material in Hub based on the idea of a system that continuously creates itself through such interplay; and the use of a system of conceptual devices to construct [U]nusual [m]etals in response to wave/particle duality that could be likened to an 'apparatus' in the Baradian sense.

[82] 'For Barad, the reality in which we *intra-act*–what she calls "agential agency"–is made up of material-discursive phenomena, phenomena in the sense of Bohr' (Schweber, S.S. & Barad, 2022). The heart of this is Bohr's position that '*we are a part of that nature that we seek to understand*'. Trevor Pinch elaborates: '[Barad's] major point is that we as humans are not outside observers of the world, but we are part of the world in its ongoing intra-activity. Ontology and epistemology cannot be separated; she advocates a form of 'onto-epistemology' – the study of practices of knowing in being – in order to come to understand which specific intra-actions matter' (2011, p. 438).

[83] Particularly Haraway, 1990 and Haraway, 2016.

[84] When asked what visual images came to mind upon first hearing of this title, some describe an aubergine-coloured soup tourine, others a say it is a tourine filled with aubergine soup, others still a soup tourine made out of an aubergine, and more – some, interestingly, based on a misunderstanding or intuitive assumption of the meaning of tourine, which is a culturally specific and scarcely used term.

[85] As in Barad's (2007) conception, the phenomenon of this project describes but is not limited to: the pieces, performers, instruments, scores, performances, locations, recordings and technology that existed within 'the cut' of the project (opposed to works outside the project).

The methodology for this project was devised as a strategy for composing a collection of works emanating from a central concept with the ability to recursively interact with each other and the core concept. By granting the project open-ended parameters (such as unlimited time and format), so long as the material of the project continues to intra-act with itself through further created works and performances it is theoretically infinite.[86]

Given the realities of the performance and programming environment, each manifestation of this project required a distinct title, and for that reason the format 'Output [X]' was chosen. To disturb a sense of innate order or linear development, the outputs were numbered without a system, and are out-of-order with the date of conception, completion and performance[87].

Outputs included (but are conceptually never limited to): the currently performed pieces *Output VI* for 3 clarinets and fixed media; *Sad Dog Eating* for 2 clarinets, PRiSM SampleRNN and fixed media; five scores and performances that provided the materials for both, as well as described manifestations of the project not yet constructed including a map of all the pieces and AI generated images that blend Aubergines and Soup Tourines.[88]

ii. Outputs

[86] Not only in the pieces themselves, such as in Cage's *Williams Mix* (1952/3) in content, and *ORGAN^{2}ASLSP* (1987) in length, but in the fact that the additive potential will continue to create new works.

[87] When using number there will inevitably be a sense of order, this is not denied since they were necessarily constructed in a particular order. But since the outputs are revisited within each other (such as in the use of Outputs IV and viii in Output VI), each time a piece is performed, the order of its creation with respect to the others has necessarily changed. The decision to use numbers without specific meaning was meant to allude to this duality.

[88] Similar to Robert H.P. Platz's *'up, down, strange, charm'* cycle in which all works are conceptually interrelated, the difference here is the works under *Aubergine Soup Tourine* are all complete realisations of the same idea that can inform each other but are not parts of a whole or intended to be performed together.

The Aubergine Soup Tourine project was developed in conjunction with University of Leeds composer Dr Scott McLaughlin's AHRC-funded The Garden of Forking Paths Project and RNCM's Experimental & Exploratory Music Research Hub organised by Dr Larry Goves and Dr Sarah Watts. As The Garden of Forking Paths was developed to explore compositional strategies for working with the material agencies of the clarinet,[89] *this also became the primary focus of investigation in the early series of works included in this project.*

Collaboration with the clarinettists began in January 2020. We had one in-person session before the first lockdown of the Covid-19 pandemic. Following a consequent pause in the project, the third meeting was conducted online and remained thus thereafter. It became apparent that the technology and all of material agencies therein would be part of this process. This factor became a source of compositional interest since it enabled a further dimension of engagement with the core principles of both projects: material agencies, emergent compositional strategies, intra-action, and indeterminacy – within both the physical and the digital realm. A methodology was devised together with clarinettists Yanke Dai, Laurel Saunders and Grace White to both listen to and capture performances that positively engaged with the material agencies of the apparatus.[90] Rather than using headphones when recording, the performers captured the computer audio together with their own performance. This created a blend of live and technologically mediated sound. Since Saunders and White shared accommodation, their live sound could interact physically, creating an additional axis of sound intra-action missing elsewhere in the ensemble (see fig. 6.1).

[89] Including the performer/clarinet combination and their environmental situation.

[90] The apparatus being the network of devices connected through the internet to online meeting software and includes the performer/instrument pairs and their environmental situation.

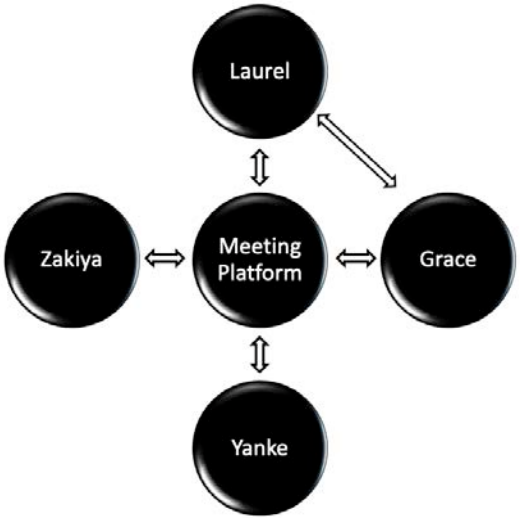

Fig. 6.1 – *Output VI*, diagram of sound interaction, live, transmitted via Zoom, and as captured through devices.

Including the one live workshop with Dai before the pandemic, and a single online workshop with Saunders before the line-up settled as the trio,[91] we had 6 sessions together. Each workshop involved the exploration of a different score, except for Output viii, which was performed with different rule-conditions (variations) over two workshops. The scores were developed iteratively through engagement with the ideas of materiality and the resultant effect on the quality of the mulitphonics within the combined space. This process could be mapped onto the idea of the forking paths. Following discussion with McLaughlin, a 'fork' was created in path that linked to McLaughlin's 'Daisy Chain' Project. The performers chose a series of fingerings to move between with the addition or removal of a finger (see fig. 6.2 & 6.3). We created a form for the piece during this meeting. Saunders and White then re-recorded their fingering movements and submitted them to the Daisy Chain project. 'Aubergine Daisy Chains in Soup Tourines' therefore links one branch of the path from each of our projects.[92]

[91] The pandemic situation caused a change in the ensemble makeup in the initial stages of the project.

[92] With permission by McLaughlin, in the spirit of the disruption of a more typical relationship between a composer and performer/s to the work outcome, both in terms of creative roles and authorship within that structure.

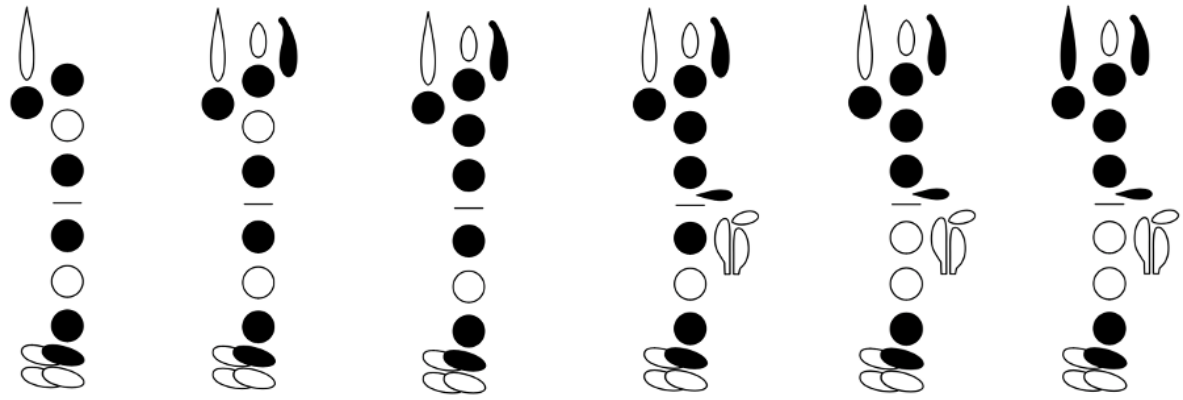

Fig. 6.2 – *Output iii*, Laurel Saunder's fingerings.

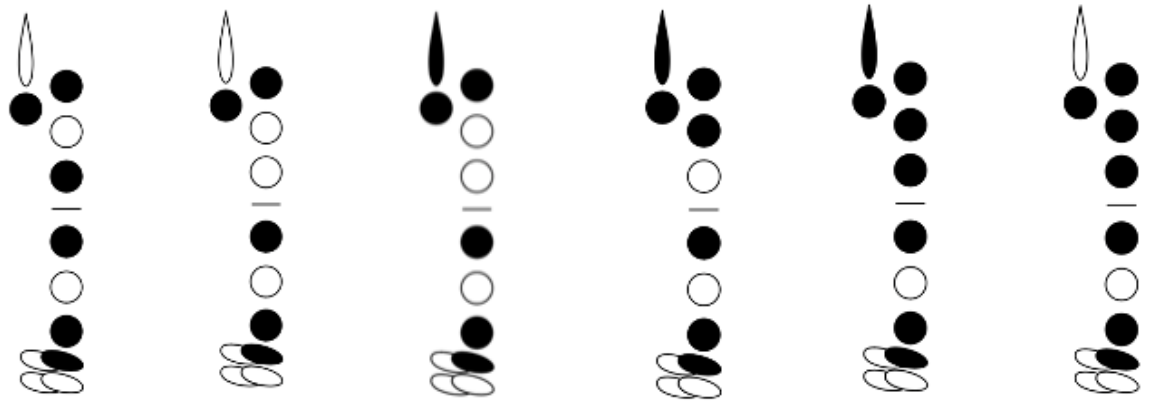

Fig. 6.3 – *Output iii,* Yanke Dai's fingerings.

In each session, the performers shared their experiences of testing the physical properties of the fingerings, including how easy or difficult it was to explore different sounds within it. All expressed that some fingerings seemed more fixed on one sound possibility that was difficult to depart from, whereas others were so temperamental that the subtle, unconscious physical changes brought about by a change in thought[93] affected the properties of the sound. This led to the creation the score for Output IV (see fig. 6.4), intended as a space to explore this

[93] Such as embouchure, air flow, bodily or facial position and tension etc.

phenomenon further, this time with intentionality as well as implicit association at work. After each run, the performers shared the pathways they had taken as well as how the objects had changed their approach to the sounds they explored within each fingering. For instance, Saunders expressed how she found the empty tourine to be different to the images due to her consideration of its hollowness, and remarked that playing with this quality in mind resulted in a change in the sound on that carried on to the next fingering.

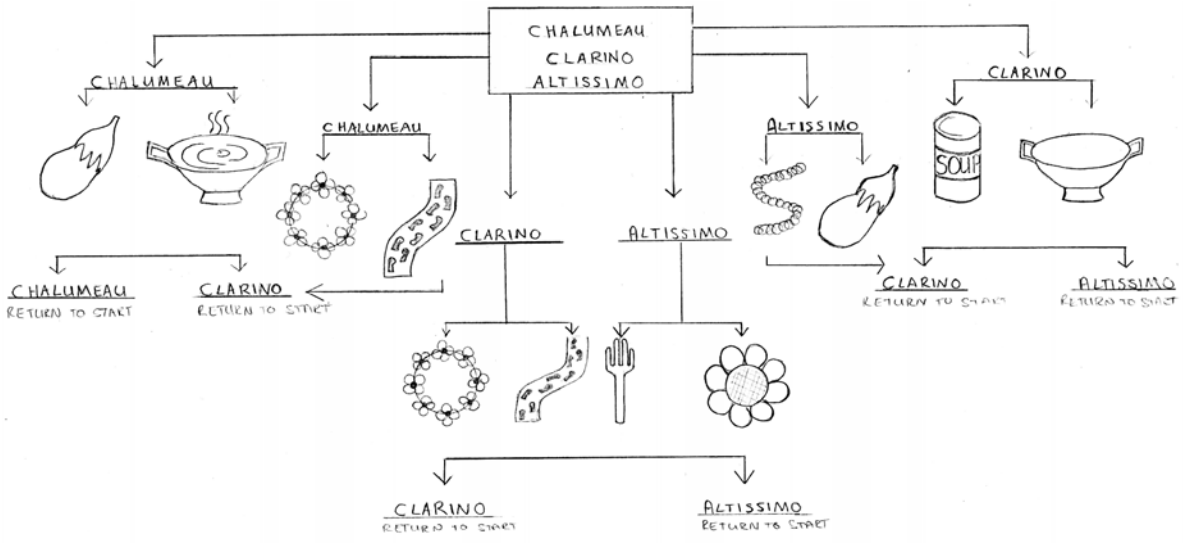

Fig. 6.4 – *Output IV*, score, picture association (excerpt).

This method of iterative development through both scores and performance proved effective for exploring the manifestations of sound materiality with respect to embodiment and psycho-acoustic manipulation. A phenomenon that reoccurred during exploration of each piece was that some multiphonics had a 'non-local' quality.[94] The performers remarked on several occasions that the source of some notes or partials could not be identified, to the degree that

[94] In 1995, Robert HP Platz authored an article discussing 'The location of sound' with examples from his 1986 work *Raumform*. This article provides an interesting look at his method for inducing similar effects through certain combinations of fingerings dynamics that he felt disrupted typical overtones. Whereas Platz was looking for instrumental techniques to produce an effect of local and dis-localised qualities, Outputs IV and VIII were developed from the discovery of the occasional presence of a non-local quality and thereafter given a more deliberate set of conditions under which it could continue to emerge under observation, rather than prescribing a mechanism though which to create it.

they were not sure whether the sound emanated from themselves, the performer in the room with them or the performer heard via the meeting platform. This prompted the primary concept behind *Output VI* – dis-locality.

Text Score Zakiya Leeming

Aubergine Soup Tourine (viii)

Imagine the text being narrated to you. When you arrive at the blanks, fill in the missing word with the first thing that comes to mind (no matter how bizarre). Play the missing word using different pitches or accents for each syllable. The pitch, dynamic, timbre etc. of the played sound(s) should relate to the word you have thought of.

Variations you can choose from:

i) Be as subtle as possible in your interpretation of the word.
ii) Be as dramatic as possible in your played interpretation of the word.
iii) Vocalise the word as you play your instrumental interpretation.
iv) Have one member of the ensemble narrate the otherwise silent text.
v) Have a narrator as above, but instead of playing the pitches, take turns to say out loud the words you think of to fill the blanks. (This version will sound like a round-robin story).
vi) As in v) but with key clicks or other percussive instrumental techniques to articulate other members' speech.
vii) Vary speed at which you attempt to make it through each paragraph.

Hello and welcome to our _____ .
Please ____ and _____ for the _____.
We ___ have many of the _____ left.
If you would ____ to have another _____ we can make _____.
___ hope ____ is suitable, if ___ _____ you can _____ it home.

Ah! You ____ _____ !
I was _____ everywhere.
_____ is such a _____ .
I don't know how _____ can _____ like this.
But it's ____ ten weeks until _____.
Maybe _____ that is finished we can _____ all of the _____ into the ___.

A drop of ____ fell onto ___ _____.
Alarmed, ___ shook vigorously until it _____.
But unknown to ___ it had _____ and was _____ making _____ .
Nobody knew until ___ had ____ it off and found __ ___ more.

__ the middle of the ____ there was a ____ found _____.
Rain had made it ____ and _____ found that strange.
Although ____ kept _____ for ways to make ____ _____,
Nobody ____ how to _____ it back.

Fig. 6.5 – *Output VIII*, score, text association.

xxiv. Output VI

This piece uses recorded audio from Output VIII*. The existing audio had a high degree of technological mediation including sound-artefacts specific to the devices and platform used to perform and record together. Some of this recorded material is treated as samples and used in a further process of composition*[95] *while others are included without further modification other than with varying degrees of sound-design manipulation intended to obscure the origin of the affect.*

The work was impacted by the paradoxical nature of our shared investigation, particularly the notion that we had spent so much time exploring the properties of sound and their physical, psychological and environmental factors in a space that did not exist – at least not in the traditional sense. The only sound waves that interacted acoustically within the same physical space were Saunders' and White's, making them the only physical audience to another's sound, whilst Dai was the only performer experiencing his physical sound in its original form. All performances arrived at my ears modified by technology, the materiality of which was evident. *Output VI* is therefore a response to these ideas of non-locality, dis-locality, unknowable origins and authorship of sound. To take the concept one step further the work was constructed as an electronic piece from the audio collected during the two workshops on *Output VIII* (see fig. 6.5 for score). The audio from each perspective (performers' phones with zoom in the background and the zoom audio itself) was layered. A series of sound design treatments changed the degree to which each perspective was audible, and at times moved through each. To further displace the notion of origin and authorship, some sections remained as they were recorded during the workshops, whilst others were treated as potential samples, undergoing a further compositional process of restructuring. The additional sound design elements also had an additional camouflaging effect on the origin of sound materiality and

[95] Including cutting, re-ordering and repetition as well as sound design treatments.

change, whether by zoom, the recording device, the internet connection, the instrument's properties itself or the sound design.[96] The piece is divided into four sections, each with a different combination of these types of authorship, creation, and mediation.

Fig. 6.6 – *Output VI*, fixed media, (mvt 4).

The visual component of the piece (see fig. 6.6) explores the concept of dis-locality through an experience of Ehler's Danlos Syndrome, a condition that can involve an impaired proprioceptive response – an inability to precisely sense where one's limbs are in space (Clayton et al., 2013). There are choreographed and improvised gestures throughout, set and

[96] Some multiphonics already had a high degree of 'distortion' in their acoustic sound, which lent themselves to this blurring of boundaries.

re-set across the four virtual spaces (the arrangement and treatment of the visual aspect) that correspond to each musical section.

The process for composing pieces informed by observations made within an iterative series complemented my intentions in the *Forking Paths* project – to explore the materiality of the clarinet with respect to multiphonics and performer/instrument/environment systems. This was a deliberate move away from what could have been a systematic, top-down exploration resulting in pages of fingerings[97] and toward a more embodied, conversational, phenomenological-minded excursion that granted space for the agencies of each system to co-exist rather than attempting to flatten them out. The visual component was conceived whilst creating the audio, and I found this exploration of a complementary concept in another medium provided an interplay that worked to extend and synthesise the overall work.

xxv. Generative – Machine Learning

'Like the invention of applied pigments, the printing press, photography and computers, we believe machine intelligence is an innovation that will profoundly affect art' (Arcas, 2020, p. 112).

Machine Learning is the newest technology available to composers, and like all that came before, has both similarities as well as differences in its potential to impact a creative process. I predict AI will also eventually have some identifiable, quintessential 'sounds' arising from limitations of the technology itself combined with materiality of all objects within the system (programme, platform, hardware, format of dataset, etc.), as do many of the mediums

[97] A systematic approach is enticing for its prospect in providing a resource that can be carried from one composition to the next. The reason I wanted to consciously move away from this was firstly because such charts can be found elsewhere, and secondly, they are of limited use when considering the differences in every performer/instrument system and the instability of many multiphonics.

previously explored. It likely too early to identify these inherent qualities,[98] but the opportunity to explore what those might be was appealing.[99] That opportunity presented itself when I was invited to be part of the first Machine Learning for Manchester (MLM4M) group and commissioned to create a piece using PRiSM SampleRNN for Future Music #3. The dataset collected from the ongoing *Aubergine Soup Tourine* project possessed interesting qualities when considered as training data for a machine learning model, and it was both for this reason and the potential to integrate ML into the iterative human/machine cycle of the ongoing project that it was chosen. The dataset featured the same type of instrument throughout (the 3 clarinet/performer combinations), but as established, not the *same* instrument, a difference heightened within the recording environments previously documented.[100] Since the pieces in the training dataset all shared a common interest in the exploration of multiphonics, there was a high degree of similarity within the dataset both in the type of material that was recorded and between the recordings taken from different perspectives.[101] The model was trained by PRiSM research software engineer Christopher Melen using PRiSM SampleRNN, a process that

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[98] Especially given the variability on both sides of the equation – inputs (data) & training (programmes) that together produce the outputs.

[99] As with early explorations into phonograph, tape, computer music etc, I expect early pieces in this medium are likely to manifest a higher degree of this latent 'AI' sound, much of which will be smoothed out by a wave of 'problem-solving' hacks, tweaks, training etc. Together with the nature of machine learning itself, I believe the 'sound' of AI will therefore become less dominant as the training gets faster and the generated material becomes more convincing, and less distinguishable from the source data. Since we can already generate variations such as those through aleatoric, improvisatory and indeterminate systems, it seem that (dependent on use) some of the unique potentials of AI may become less pronounced over time. Although these developments will certainly merit artistic enquiry, I was keen to explore the latent materiality of this early system, together with its 'raw', 'glitch' type aesthetic together with the occasional 'uncanny valley' aspect of identifiable timbres.

[100] Again referring to the manifest properties and symbiotic relationship between performer, instrument and environment, and further mediated by the online transmission and recording devices used to capture the performances.

[101] E.g., Saunders' performance of a single multiphonic is heard 3 times across the dataset - the first from Saunders' & White's perspective, the second from Dai's, the third from the zoom recording, each with a different disturbance in the sound as a result of the recording and streaming technologies.

went 'well' (for full training data, see APPENDIX B).[102] Melen provided ten samples from eight epochs (training cycles), and twenty from a further two epochs at two different temperature settings ('chaos' – or the frequency with which you want statistically less common eventualities to feature). Given the unpredictability of the resultant material, I decided to wait until I had received the generated samples before constructing a plan for the composition of the piece.

xxvi. Sad Dog Eating

Sad Dog Eating follows Output VI in an iterative compositional process that explores technological mediation and distributed creativity, here introducing possibilities afforded by machine learning. The dataset was created from the recordings, and the self-similarity of the dataset captured during the previous workshops appeared to be an asset to this process. The introduction of this technology enabled further exploration of the emerging spiral of human/machine intra-actions that began in 2020.

In a compositional strategy informed by the machine learning process, samples were selected from the generated material to 'chunk'[103] into loops I created by layering generated samples[104] for the performers to learn. Saunders and White then created acoustic loops informed by the layered material. All three stages of material generation are present in various forms in the final piece, named after White's interpretation of a particular sound in one of the loops. In a mirror to our iterative cycle in which human/machine origins became ever more obscured in continuously blended outcomes, White's description struck me as a title that perfectly captures this ambiguity. The visual component was created from images produced with online machine learning image generating tool *Artbreeder* (.artbreeder.com), with parent images

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[102] There was no overfitting or undesirable underfitting – from early on material generated from the model somewhat resembled the training data as opposed to noise and glitch alone.

[103] Chunking strategies involve the splitting of a longer piece of data (here a concatenated audio file) into segments to learn in batches.

[104] The selection and order of the layered material was a matter of musical choice.

chosen from the tags ‘sad’, ‘dog’, and ‘eating’. As with the audio process, some images are presented in their raw format, whilst others have undergone further digital modification using tools in Final Cut Pro.

Audio types and sources included in the piece:

- Stacked raw recordings from the dataset (some shared with *Output VI*)
- Individual raw generated samples
- Saunders’ & White’s acoustic responses to loops I created from layered, generated samples

The piece is bookended with Saunders’ whistles, followed (and just preceded) by the performer’s acoustic reinterpretations of the loops I created from generated material. These loops were recorded separately and thereafter treated as samples, used to construct the final work in an order and combination I chose. Selected generated samples are then presented, the first of which reminded me of a concerto-style entry where the ensemble stops to mark the dramatic arrival of a featured instrument.

The central section is underpinned by a gradually tapering texture made with every recording taken during the Aubergine Soup Tourine Sessions and that comprised the ‘raw’[105] dataset for the model. Both the generated material of the machine learning model and sections of the acoustic loops weave in and out before returning to a fully acoustic sound and finishing with a restatement of Saunders’ whistle. This format marks a movement through a general ’human – human/machine – human’ progression.

As an iterative machine learning cycle, the reintroduction of the new piece to the dataset could potentially result in a perpetual cycle of work creation, either with or without the addition of

[105] Raw only in the sense that no further technological treatment had been applied since the collection of the recordings. As mentioned in the introduction to this chapter, these recordings all had a certain degree of technological mediation that modified the sound to a greater degree than a standard recording session with typical recording equipment.

new acoustic interpretations of generated material to this process. Whether this amounts to an outward or inward spiral of creativity I have yet to discover. Perhaps this cycle (if closed to new material) could become a type of ML cousin to Lucier's *'I am sitting in a room*,' where repetitions in the cycle might enhance the particularities of the system (the software program instructing the model and its latent properties) over time.

I found this mix of open scores, performer choice, improvisation and the range of technological apparatus mediating it within an iterative cycle highly effective in exploring ideas of human-machine distributed creativity. On a purely sonic level, the combination of layered original audio with the distinctive features of machine learning and online platform artefacts produced an effective dialogue and at-times synthesis of these disparate qualities. On a conceptual level, machine learning processes were themselves an interesting, new system to draw from in creating a compositional methodology that considers an ongoing role of the performer in the process.[106]

[106] Many decisions taken in this piece were the informed by considerations of the developing conversations around the role and impact of machine learning on music. Aptly put by Rutherford-Johnson, 'Technological, social and political developments can and do influence developments in art in two ways: they either enable them or they inspire them. That is, a new development can make certain artistic aims possible (through the creation of new technical means, for example), or it can inspire new aesthetic propositions, not necessarily by making use of the new technology, but by pursuing some of its wider implications' (Rutherford-Johnson, 2017, p. 17). By considering the ongoing role of the live musician and exploring the characteristic aspects of this technology and its processes, I developed a compositional strategy for working with this technology I found artistically and ethically satisfying.

CHAPTER 7

CONCLUSIONS

xxvii. PERSONAL PRACTICE

At the beginning of this project, I had been exploring scientific theories, patterns, and processes in my practice for some time, although there had never been a formal decision to do so. By the end of my master's degree, my propensity to be drawn toward 'thinking compositionally' through these topics was something I was both aware of and keen to explore further. This creative project sought to build a better understanding about why practice was often informed by science, how that manifested in compositional decision-making and where that could lead my practice if this was formally investigated.

Similar to the way in which Michael Parsons describes systems composers, this approach had the effect of providing 'relational procedures' that are 'seen not as a means of complete control, but as a method of inquiry' (Parsons, 1976, p. 816). The objective was to construct musical works through materials and strategies drawn either implicitly or explicitly from my understanding and framing of scientific concepts, as opposed to 'representing' or 'translating' the extra-musical stimuli. As expressed by Boulez, 'in the composer's imagination these different external "acquisitions" assume an exclusively musical form and become specifically and irreversibly musical concepts'(1990, p. 75). Boulez also agrees that influences of this kind must be by 'analogy rather than by any literal application…As I see it, the most important level at which this fertilising process takes place is the very deepest, namely that of thought-structures – the imagination adapting outside resources to new purposes in a kind of fertilising process' (p.75). Through exploring my own composition strategies further, I discovered similarities between those of mine and other composers that related to concepts of mapping and mimesis. This led to the concept of metaphorical mapping as a way to view compositional responses to science that defied expectations of systemisation and allowed for a more poetic response to ideas encountered in science.

The assumptions about the nature of an artistic project exploring science that I encountered early in the research led me to question my own assumptions about 'science' as a single thing: the modern scientific method. An investigation into the definitions and conflicts at the nexus of historical, social, and philosophical discussions about science introduced a wealth of knowledge and knowledge-systems that helped to contextualise my own understanding and approach to science within this artistic project. This inquiry also led to an expansion of my practice not only on a theoretical level, but also in the exploration of different performance approaches such as the internal narrative-theatrical performer approach of *Scaffold II* and *Mark I*, the use of open and indeterminate scoring within an 'investigatory' framework (*A length of String*), and the construction of works within a global series (*Aubergine Soup Tourine*), influenced by consideration of philosophical discussions on modern scientific questions arising from quantum theory with particular reference to Barad (2007) and our relationship to notions of humanity and technology (Haraway 2016).

Working with scientists on topics I had been unfamiliar with proved advantageous for the development of my practice, since I felt the need to create new approaches to understand and navigate these new systems. Working with Andrews on *At the Node of Ranvier* proved a turning point in my practice because of the impetus to design a system of interaction between performers. This moved the conceptual construction of future pieces beyond the musical parameters of pitch, rhythm, texture, and timbre. The development of *[U]nusual [m]etals* with Professor Brust was similarly ground-breaking for my practice. By using both sound and visuals to focus on a single concept, I explored not only new media and tools (sound design and filmmaking), but also a more focused approach to the investigation of this sound-type over the duration of the piece.[107] These informed choices made in subsequent pieces, such as the decision to limit the percussion in *Waterwheel* to primarily electronically driven sounds across

[107] An example of the opposite extreme that I more often gravitate toward being *Mark I*, a piece presenting millions of possible permutations, and the middle-ground of *A Length of String* and *Scaffold II* that explore a medium-sized range of chosen combinations.

a smaller collection of instruments,[108] a direction I would have been less likely to have taken prior.

Collaborations with health data scientists, doctors and researchers proved revelatory to the existence of a population of professionals with prior histories in, or desire to explore music. The technical challenges presented by rehearsing, recording and mixing *Dawn on the Morning After the Storm* for an online performance further developed skills in mitigating different tuning systems through problem-solving and sound design. The development of an effective methodology for creating music together with people working in challenging circumstances has also led to further projects in health, such as a new Wellcome Trust grant to develop a chamber opera drawing from the history and development of vaccines.

Exploring the procedural possibilities and material agencies of current machine learning environments for music has provided my practice not only with new tools and techniques, but also a new outlook on human/machine hybridity and distributed creativity. Following from remediation discourses that began at the advent of 'new media' proposing media already 'cannot be conceived as anything else than hybrid' (Kember & Zylinska, 2012, p. 7), this work is informed by a posthuman view to 'treat these new nonhuman kin respectfully and reciprocally–not as mere tools, or worse, slaves to their creators' (p.40). The development of an iterative/generative cycle of composition has had a significant impact on the way that I view and approach the idea of identity, continuity and development of individual works and work-series, and I am continuing to develop and expand on these skills and artistic methodologies in new works.

xxviii. ARTS/SCIENCE COLLABORATIONS

[108] As compared to the array of instruments, mallets and techniques in *His Black Box.*

My collaborative series with Dr Andrews and Professor Brust as well as health and data scientists follow from a modestly sized but long historical tradition of composer/scientist collaborations as discussed in the Practice Review. Working with these researchers has not only been a catalyst for growth within my practice, but also contributed to a growing re-emergence of science/arts collaboration in recent years. There is now a greater awareness of the space that these collaborations can occupy between the disciplines, and ways in which they can benefit not only the artists and scientists involved but also the public, opening out discussions of current research that can be otherwise obscure and unintelligible into a more accessible and enjoyable format.

Collaborations with heath data scientists, doctors and researchers led to the discovery of a mutually beneficial artistic space for musicians, scientists, and public alike, much larger than I had previously understood, leading to the realisation of an interest and demand that is currently underserved. Developing a relationship with doctors and scientists in this area has led to further contact with other interested parties, including three approaches to PRiSM and myself directly from doctors and health researchers in attendance at the #MusicSaysDataSavesLives event with the CHC concert. The endeavour to contextualise this research within a wider practice also led to the discovery of a gap in the literature for this type of artistic collaboration relative to other forms, something that this commentary and portfolio seeks to highlight as an area for further research.

Being part of a working group investigating new compositional technologies such as the MLM4M group has demonstrated the potential for collaborations not only between computer programmers and composers but also between artists working in the field. The presentations by my colleagues at RNCM Future Music #3 demonstrate the enormous range of potential in integration of machine learning with wearable technology, kinetic sensors, virtual reality devices to produce new artistic models and outputs.

This creative research has found that there is a greater potential for connection with scientists than ever before, and the ways that they can inform and expand artistic practice is as endless as it is impossible to characterise, leaving space for anyone and everyone to take part, including

(if not especially) those unfamiliar or hesitant about the meanings and roles of each in our society.

xxix. METAPHOR, NARRATIVE & SCIENCE

There is a rich contemporary field of practice that includes both composers responding to science in different ways, as well as composer-scientist collaborations, and this is the field to which I am contributing new knowledge in the form of reflective research, critical context, and an individual artistic response. In particular, this research demonstrated how exploring topics through metaphor and narrative with both scientists and performers can be a fruitful way to engage with extra-musical ideas in music. This approach also proved versatile, allowing for layered narratives, and different forms of symbolic representation that could be used with a range of scoring and performance types, including the involvement of technology and hybrid performance environments. This research discovered that there remains a considerable space in the literature for further exploration of music informed by science, particularly with regard to metaphorical and poetic approaches.

xxx. LEGACY

This Portfolio and commentary demonstrate that there is a wide range of possibilities, many still untapped, in the ever-changing space between science and arts. In the face of current challenges such as digital misinformation strategies, climate crises, global pandemics, and the ongoing effect of financial crashes and instability, we are living with a heightened awareness of the role of science and technology in both the creation of these problems as well as the politics in using the same for change. This project started from a personal interest in my own tendency to make compositional decisions informed by ideas in science, but expanded to include considerations of the role that artistic practice can have in these broader conversations.

The legacy of the projects with heath currently appears to be significant for this body of work, as there has already been a noticeable effect on the wider health and social care community in awareness and involvement in collaborative projects with composers.

The impact of my work with the individual scientists in the collaborative series is apparent in the significant developments in my compositional practice. Additionally, the visibility of our projects within the wider community has demonstrated some opportunities and benefits of these collaborations.[109]

It is too soon to judge the impact of the explorations into machine learning, but as with the composer/scientist collaborations, the visibility of this option will no doubt have been impacted through my discussion of the experience with other artists, presentations at conferences, and the piece itself.

Whether composers choose to engage directly with scientific or technological developments, those developments affect the artistic and cultural spaces we work within. For composers who choose to engage with those systems directly, our work can create a space for discussions not happening elsewhere, not accessible by other means. It is my hope that through the works constructed during this creative project and the connections made, this important artistic and cultural space will continue to grow, the 'two cultures' mentality splitting the human experience into 'artistic' and 'scientific' can be left behind and a new synthesis can emerge that equips everyone for the important discussions of their time. This work has made clear to me the reason that arts/sciences have a long tradition of interconnection and collaboration, and I hope that this project demonstrates the importance of the continuity and ongoing development of this legacy as well as highlighting the breadth and depth of opportunity still available for artistic enquiry between artists and scientists.

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[109] The collaboration with Andrews was part of the first 8^3 PRiSM project, and many more scientists and composers have become involved in subsequent years, each presence adding to this growing field.

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APPENDICIES

APPENDIX A: Additional Works

xxxi. Mark I

This work was developed from of the idea of modelling aspects of the scientific process in music. The score acts as a map of available permutations that cover individual and combined sound types between the instruments. In each rehearsal or performance of the piece, the aim is to explore combinations with a focus on the acts of observation and discussion. This piece draws on both aleatoric and performance art traditions.

The purpose of this work is to experiment with the differences and similarities of the length and timbre of resonance within the ensemble. This can be approached either as a meta-instrument, a collective of individual instruments, or through a variety of hierarchical structures.

The score was created out of a desire explore a large number of combinations of these related, but acoustically different instruments. The performer is invited to adopt a mindset of someone who is carrying out research.[110] By treating the observations of resonance, weighting and individuality or cohesion as 'aims' of the research, practice becomes a 'methodology', and a performance of the piece becomes akin to 'publication'. The performers are invited to situate this performative element within the parameters of parody, homage, or artistic allusion to the practice of science and include the discussions, choices and observations as part of any performance.

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[110] To distinguish this mindset from an ensemble rehearsing and performing within more typical bounds of 'practice as research', the purpose of this mindset is to increase the focus on ongoing investigation, observation and sharing of findings as the *primary act* of performance, rather than in service of it.

Progress through piece can be approached in several ways, including systematic, chance-based, or musical methodologies (where the latter is based on choices made for personal musical reasons). The 'Form' section (see Fig. A1) provides the option to perform a chosen combination of other figures with the given shape acting as a global structure. Similarly, the 'Expansions' box can be applied to any existing set of choices, but is optional. All other parameters should be agreed between the performers before a run (the discussion for which would be the start of the piece in a performance setting). This can be with the ensemble all performing from the same set of options, or each parameter (e.g., pitch) can be set differently for each instrument. For instance, if 'Attack/Decay/Sustain' was chosen as 'A' for the vibraphone, 'B' for the harpsichord and 'C' for the piano, they would each play the shape that corresponds to their instrument, and if a fixed pitch 'C' was chosen for all instruments, the intervals from this pitch available to each instrument could be different. To pre-select or record the active parameters in each run, a choice chart can be used (see fig. A2), however this is not necessary, and different approaches to navigation should be viewed as equally valid.[111]

The piece was workshopped by Riot Ensemble and the ensemble's approach to the piece was discussed prior to their arrival. The ensemble members chose to employ both musical and chance-based strategies for exploring the piece.

[111] This choice-chart was devised after the workshop, to aid selection and documentation of each run for ensembles interested in this approach.

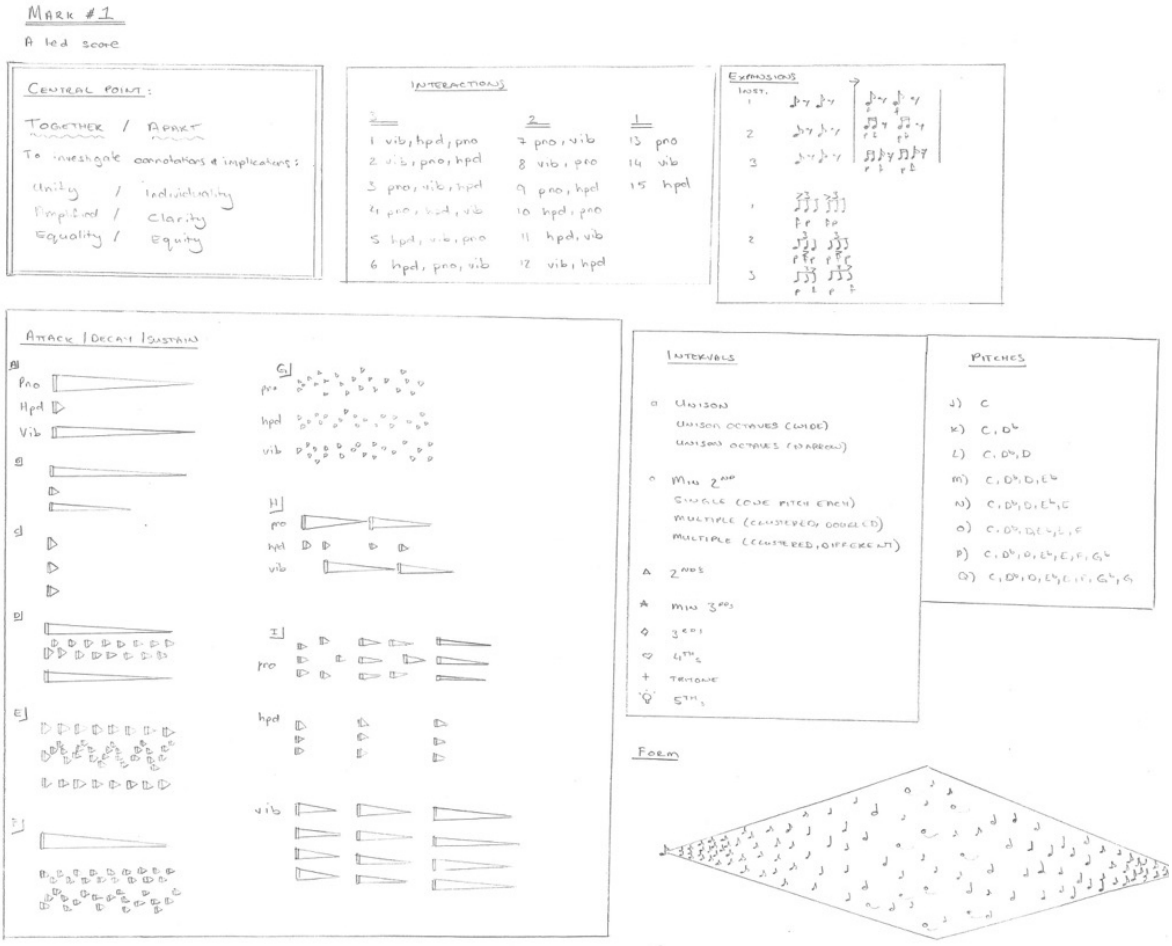


Fig. A1 – *Mark 1*, score.

The recording included in the portfolio is of the final run, and the options selected were: ‘E’, ‘interaction 6’, ‘J’,’ 4ths’, ‘tritones’, ‘min 3rds’, ‘Expansion’ as you wish, ‘Form’.

	√			
Run 8	All	Vib	Hpd	Pno
Central Point				
Interaction	6 [hpd,pno,vib]			
Expansion				

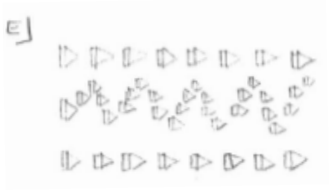
Attack/Decay/Sustain				
Intervals	Min 3rds, 4ths, Tritones			
Pitches	J [C]			
Form (Y/N)	Y			

Fig. A2 *Mark I*, Choice Chart – run 8.

The performers commented that the activities within the work, together with the premise of an investigatory outlook created an environment that was different from a standard practice or performance session. In particular, they expressed how the typical focus on not producing 'bad' or 'wrong' sounds was eliminated, and they were able to follow their own interests. I found this to reflect the purpose well, since the objective was to create a piece within which a type of musical investigation could occur, led by the ensemble.

xxxii. Duel Dances

This work was a culmination of the first period of research looking at different types and degrees of musical relationships to scientific theories. The piece explored the idea of mass transfer – where mass is a collection of sound objects moved between groups of instruments arranged within a space, informed by the Mass Transfer process of a binary star system.[112]

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[112] As two stars orbit each other closely, some of the mass of the larger star can be pulled in the direction of the smaller star and be caught in its orbit, pulled in and eventually absorbed by its partner. What had been the larger star has now become a White Dwarf, and the incredible gravitational pull of this star starts the process again in reverse. This can lead to a nova explosion when the white dwarf pulls so much hydrogen from the Red Giant that it results

Duel Dances explores the events of such a binary star system. Originally conceived for two string quintets arranged opposite one other on stage, with a string trio and percussion duo between them, the piece was later reworked for orchestra in a typical stage arrangement. The figures provided here are from the earlier version. The placement of the original three ensembles on the stage was a spatialised response to the idea of material moving physically from one location to another. When re-written for orchestra, this concept was applied to instrumental groups. The material from string quintet 1 of the original score was reworked for winds, brass joined the percussion to form the central group, and the strings retained material from the original string quintet 2. This maintained the idea of discrete groups in distinct spatial areas, this time in a different shape.

An expanding chord in the outer group (string quintet 1/wind) gradually envelops the central group, an idea drawn from the expansion of a red dwarf star that continues until the Roche lobe touches that of the neighbouring star. This begins the transfer of mass/musical material previously described. The expanding chord elicits a swelling sound that could be understood as an object that is growing larger.

The transfer of sound mass is described with the cascading movement of the triplet figure from one outer group (quintet 1/winds) to the central group (percussion/& brass). The central group is representative of the limit between the groups, where material can travel through (but cannot pass directly from one outer group to another). Conceptually, this is related to the Roche lobe – the limit of the star's own gravitational pull – in the mass transfer process. The triplet material arrives the outer limits of the second outer group (quintet 2/strings), where the 'outer' limits are the instruments with the highest range (violin I & II).

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in hydrogen fusion from the intense temperature of the White Dwarf. Source: Modisette, J. L. (1980). Mass Transfer between Binary Stars. *Highlights of Astronomy*, *5*, 863–865.

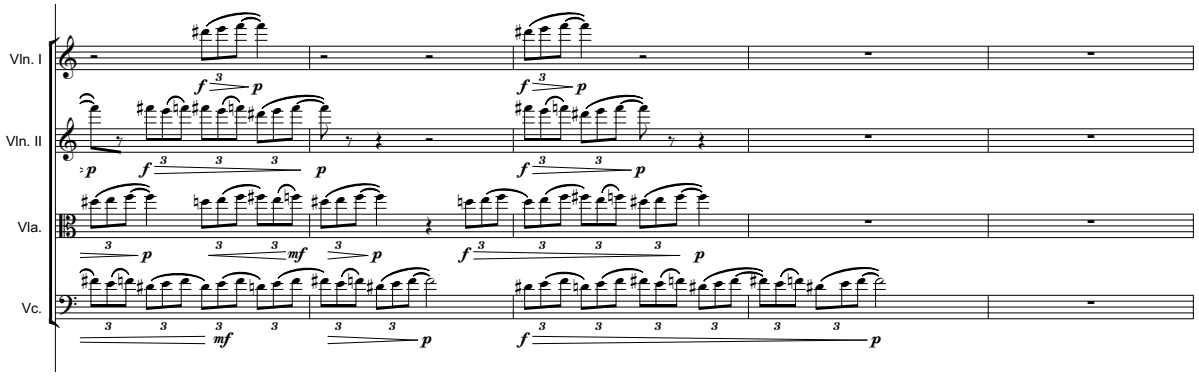


Fig. A3 – *Duel Dances,* string quartet 1, *triplets begin to travel out toward the star's outer limits* (b.117-121).

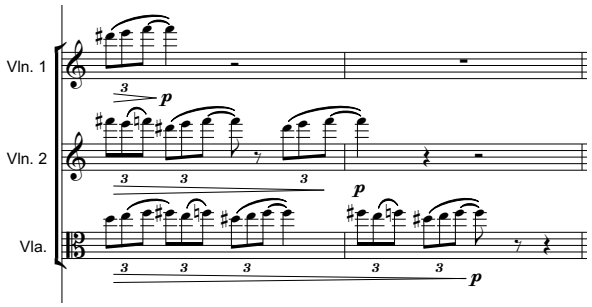


Fig. A4 – *Duel Dances,* string trio, *triplet material passes through the string trio* (b.124-125).

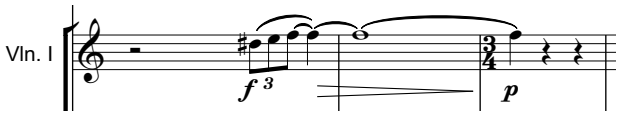


Fig. A5 – *Duel Dances,* violin 1 (quartet 2), *triplet material arrives at the second string quartet* (b.126-128).

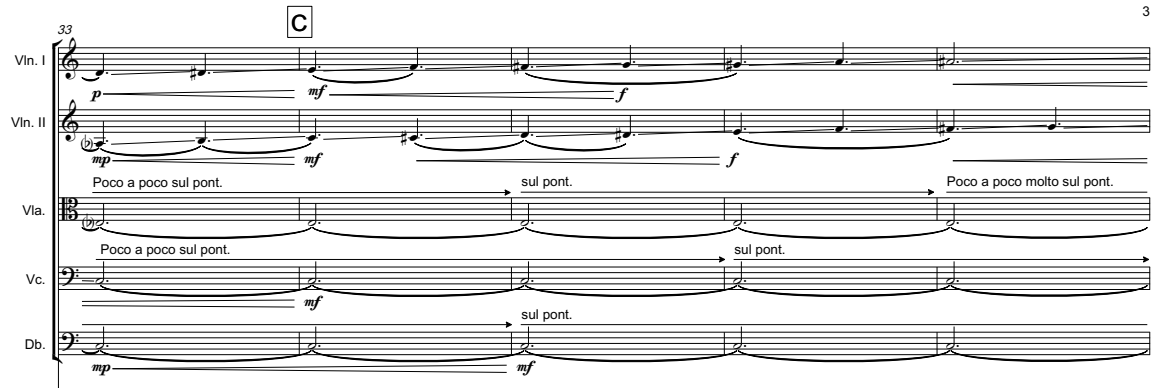


Fig. A6 – *Duel Dances*, string quartet 1, g*lissandos producing a swelling effect* (b.33-37).

A mentioned, this piece was the culmination of the early research (omitted from the commentary for brevity), investigating ways that scientific ideas can inform structure of pieces as well as choice and use of parameters. The original orchestration of the piece added a new consideration to that mapping; spatialisation. This was later adopted into a more traditional arrangement of instruments to make performance more practical, however the consideration of these other elements informed the consideration of arrangement of instruments in the performance space for later pieces in the portfolio. Some of the ideas for expanding musical material first explored in this piece informed the creation of *Monolithos,* as did the development of the glissando harmonic string technique trialled en masse, developed further in the later work.

APPENDIX B: Training Data – *Sad Dog Eating*

Below is a summary of the data provided by PRiSM Software Research Engineer Christopher Melen along with screenshots from TensorBoard pertaining to the training sessions for the *Aubergine Soup Tourine* dataset.

DATASET

The source audio consisted of a single wav file downsampled to 16kHz. The dataset was then created by chunking it into 8 second chunks, with an overlap of 6 seconds. This produced a folder of 2616 files.

TRAINING

The model was trained on PRiSM's second Deep Learning System, which has an NVIDIA GeForce RTX 3090 GPU, with 24GB of built-in RAM. It was trained with the following parameters (see the SampleRNN README[113] for a full explanation of each parameter):

Batch Size: 64
Learning Rate 0.001
Sequence Length: 512
Frame Sizes: 2, 8
Dimensionality: 1024
RNN Type: GRU
Number of RNN Layers: 1
Quantisation Type: MU Law

[113] https://github.com/rncm-prism/prism-samplernn

There were 4 training restarts, with the training eventually reaching epoch 330. The model was saved to disk (in) TensorFlow checkpoint format every 5 epochs. A single epoch took around 14 minutes to complete, which is neither particularly slow nor particularly fast.

AUDIO GENERATION

Generation of audio is done using a separate script, which loads a saved model from disk into memory and generates audio samples from it, saving the output to disk in wav format. Multiple files of any duration can be generated in parallel. Since the model had been saved during training every 5 epochs there were many versions of the model to generate audio from. The following epochs were selected:

100, 110, 120, 130, 230, 260, 265, 280, 310, 330

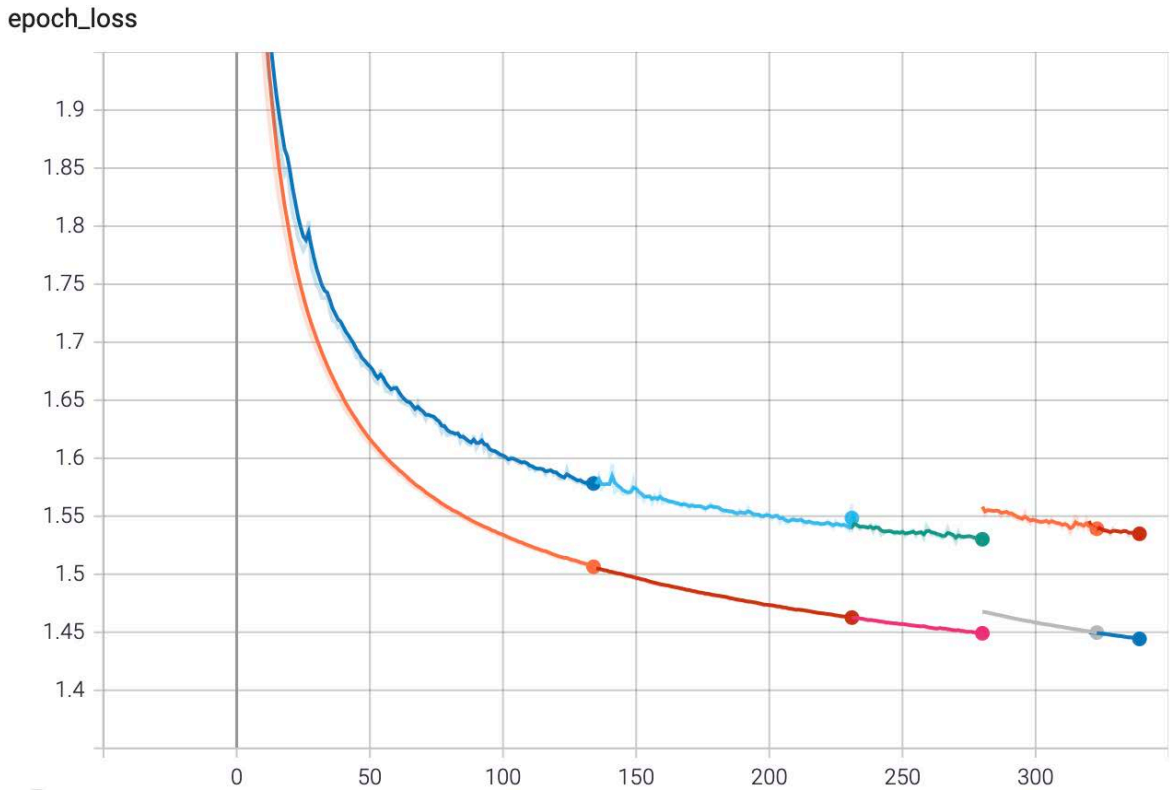
Decisions regarding which epoch to generate from were based on analysis of the training metrics, as viewed in TensorBoard.

An important parameter for generation is the temperature. This controls the amount of 'randomness' in the generated samples and is generally a number between 0 and 1 (although it can be higher). The higher the value, the more surprising the generated samples. It works this way because what the model produces is a probability distribution for what the next sample will be. It generates this based on the previous sample, and the weights it has learnt during training. But the temperature parameter is like a perturbation to this process, introducing an element of chaos (heating things up, which is why it is called temperature). In these training sessions the temperature was usually 0.975, but the following epochs seemed interesting enough to suggest playing with different values:

100 - 0.99
110 - 0.95, 0.99
330 - 0.975, 0.99

TRAINING METRICS

The model training generally quite well. There was no overfitting. The model could have continued to improve with further time on the machine. The progress of the training can be seen from the TensorBoard loss chart. The chart shows the two main metrics, the training loss (bottom line) and the validation loss. The dots/gaps are the points where the training was stopped and then restarted. Think of 'loss' in this context as the difference between the model and the target dataset, at each step in the training. The validation loss is the loss measured against the validation dataset, which is a small subset of the main dataset, selected prior to training, and which the model never learns. It does this in order to see how well it can respond to data it does not know, how well it can generalise. If it has difficulty with the validation dataset then the validation loss will start to climb, indicating overfitting. In this case there was no overfitting, although the model certainly had not finished training, and could have learnt more. (Dr Christopher Melen, PRiSM Research Software Engineer)



PORTFOLIO OF COMPOSITIONS

xxxiii. List of Accompanying Works

1. Monolithos (orchestra)
2. His Black Box (small ensemble)
3. A Length of String (percussion quartet)
4. Scaffold II (piano duet)
5. Rennervate (small ensemble)
6. At the Node of Ranvier (piano machine & small ensemble)
7. [U]nusual [m]etals (singing bowl & fixed media)
8. Surface (small ensemble)
9. Waterwheel (small ensemble)
10. Hub (wind quintet)
11. Dawn, on the morning after the storm (bagpipes & small ensemble)
12. Output VI (clarinet trio & fixed media)
13. Sad Dog Eating (clarinet duo, fixed media & PRiSM SampleRNN)

xxxiv. List of Recordings

1. Monolithos (6’08”)
2. His Black Box (11’24”)
3. A Length of String (6’55”)
4. Scaffold II (6’28”)
5. Rennervate (4’51”)
6. At the Node of Ranvier (9’01”)
7. Surface (5’58”)
8. Waterwheel (10’18”)
9. Hub (9’43”)

xxxv. Online Performance Links

1. [U]nusual [m]etals (singing bowl & fixed media)

   https://www.youtube.com/watch?v=1t0OTWG4NCg

   14:30min – 19:42min

2. Dawn, on the morning after the storm (bagpipes & small ensemble)

   https://www.youtube.com/watch?v=e0l3S04TfFY&t=2s

   From 0:00 to 9:54min, 'In Conversation' from 9:55min – end (34:23min)

3. Output VI (clarinet trio & fixed media)

   https://www.youtube.com/watch?v=Sw3G2HpQ9fs&t=1602s

   18:36min – 28:42min

4. Sad Dog Eating (clarinet duo, fixed media & PRiSM SampleRNN)

   https://www.youtube.com/watch?v=_3KqZ0z6CjA&t=1s

   From 1:45:30 to 1:52:44

Total Run Time: 103'3''