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Sonic Vessels: Imbuing Performer Presence in Musical Artifacts

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Abstract of Doctoral Dissertation of Academic Year 2023

Sonic Vessels: Imbuing Performer Presence in Musical Artifacts

Category: Design

Summary

Throughout the past few decades, technology has become increasingly intertwined with music composition and performance practices. Collaborations between musicians, composers, researchers, scientists, and many other disciplines have become more common than ever. This rise in cross-modal collaboration has introduced many novel and challenging possibilities, while also challenging long held traditions in performing arts.

As with any sort of mixed-discipline collaboration, there are many issues which need to be tackled. This co-existence of varying expressive and analytical forms can both modulate and elevate the possibilities of these practices and introduce imperative questions which must be explored.

In my work, I aim to explore and refine a framework for the utilization, implementation, and exploitation of perceived presence into external musical artifacts in predominately sonic works. I will discuss a number of previous works which have served as the basis for my exploration, examine the historical and methodological context of adjacent works, present several in-the-wild exhibitions, and propose a framework in which physiologically-driven presence is intertwined with sonic art forms.

Keywords:

liveness, sonic art, physiological sensing, music composition, public art

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Acknowledgements

The path to this Ph.D began in many ways around 30 years ago. Although I never would have guessed back then that I would eventually move to Japan and pursue this degree, everything that has led me to here was important and necessary. Not at one point was this a solo effort. I am indebted to so many people that it seems foolish to try and write this all down, but I will do my best.

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Chapter 1
Introduction

1.1. Motivation

The path to arriving here at this thesis began in full many years ago when my interests shifted from direct performative and compositional approaches to a more abstract and exploratory approach to sound as an affective medium. While I cannot specifically state exactly where this shift began, it started to take shape while I was studying as an orchestral composer. This time in my creative life was extremely meaningful in many ways, but possibly one of the most meaningful occurrences was my realization that my own work as an orchestral composer was not adequate. For me, I felt far too detached from the process by which I found myself: develop ideas alone, commit them to paper, pass this paper on to the conductor, who would then guide the performers in realizing these works, all the while the audience sat in an orchestra hall and listened to my exact thoughts and ideas. This is not what I see orchestral composition as, but rather as what I seemingly placed myself into. It was a process of self-realization and not of any sort of communication or dialogue. I found myself simply talking at the audience, instead of garnering any sort of direct engagement from this process. Over the next several years, this process would slowly evolve into the method which I am presenting in this thesis: a method for imbuing the perceived presence of a performer which can exist as a sort of semi-autonomous entity through which deeper dialogues can come to light.

My Own Musical Journey

It is important to provide some context for how I ended up where I am today. I began my own musical journey at the age of 9. For all of my childhood, I

was provided a strong backdrop of musical appreciation through my parents. My father has always been a big fan of music as varied as Tom Waits, Gregorian chant, Sade, and Tangerine Dream. My mother, on the other hand, was always drawn to artists such as Dolly Parton, The Carpenters, and pop hits from the 50's. This interesting blend of musical tastes filled my childhood home with an eclectic and exciting mixture of styles and sounds. However, while both of my parents played musical instruments for a time, neither of them were particularly dedicated to their craft. Despite this, they were always incredibly supportive and when I got the inspiration to begin my own musical studies, they were completely on board with my dream.

Under the direction of renowned educators Jim Culbertson and Steve Schepper, I was put through rigorous training that would prove to be immensely rewarding later in my professional career. My high school jazz band was given the opportunity to tour throughout Europe in 2001 and play at some of the biggest jazz festivals in the world, such as the North Sea Jazz Festival, Vienna Jazz Festival, and the Montreaux Jazz Festival. Having this kind of experience while still in my teens is something that I will always hold dear to my heart.

As I grew into my 20's and branched out from jazz music into more ambient and experimental genres, I always had a passion for creating unique and engaging works. Whether it was through intensity in my prior hardcore bands, songwriting in my indie bands, or my eventual transition into scoring for film, theatre, and dance, I always found myself rather fixated on how I could use sound to affect the people who engage with the work. This would come into play rather intensely during my time at university under the mentorship of composer and educator Marcos Balter. It was under his wing that I began to investigate novel ways of using frequencies, rhythm, and intention as a means for conveying not only conceptual ideas but also physicality in sound art. This transition was one of the more formative moments in my artistic life.

Following the completion of my Bachelor of Music in Composition from Columbia College Chicago, I made the move to Los Angeles and began my Master of the Arts in Experimental Sound Practices degree at the California Institute of the Arts, better known as simply CalArts. It was here, primarily under the guidance of Scott Cazan, Spencer Salazar, and Stephen Chiodo, that I moved further away

from sound as music and deeper into sound as a physical or psychological tool. Inspired by my previous work with dancers, choreographers, and theater groups, I explored new ways of utilizing sound as a component in multimedia installation and performance works. While sound was and has always been a major part of my artistic output, this is the time in which I began to fully grasp and explore how much more I could say with sound when amplifying it through other modalities. For instance, my final work for my masters degree consisted of an installation which involved a giant spider sculpture hanging from the ceiling. This creature was constantly playing morse code signals and number stations in many different languages. Upon deciphering the message (which nobody did), it would lead the participant to a specific hidden place on campus. In this hidden place was a cassette tape with a one-off musical work on it and a $100 bill. Since nobody solved this game, I decided to burn the cassette tape and use the money to buy some artisan cupcakes for my dog Lacey from Three Dog Bakery in Encino. In some strange way, I believe this was the beginning of my curiosity into what makes sound exist conceptually, which I will discuss later on.

All of these directions in my artistic life have finally led me here to KMD. When I began my work here at KMD over three years ago, I was intent on keeping myself open to any kind of possibilities I would find myself in. Luckily for me, I quickly found myself working with many of the same people I continue to collaborate with, and soon found myself developing what would eventually become this thesis; an at times exploratory and at times experimental means of developing predominately sonic works which can not only reflect but represent performers' and composers' presence and intention in dynamic performance practices.

In this thesis, I will present my methodology for passive presence-based sonic performance and composition. This method will rely on data acquisition methods including physiological sensing and physical sensing methods, in addition to a deep study into the performative and compositional aspects which adapt to this presentation and implementation of presence, or *liveness*. The evaluation method of these works will be comprised of qualitative analysis of interviews conducted with the performers involved in these works, a lengthy breakdown of the iterative design process of my works, and discussions with professional musicians and composers who intend on using this method in their own work. This qualitative study

will be supported by quantitative data analysis taken from performances and a lab user study on sound affect. Furthermore, a lengthy discussion on the in-the-wild performance presentations will give further context to the aforementioned qualitative and quantitative analysis.

1.2. Purpose

The main purpose and intention of this thesis is to provide the framework of a methodology to make possible new and novel forms of artistic expression, predominately within the sonic arts. The development of a novel performance methodology is an effort which not only provides artistic and expressive inspiration for myself but extends out to the greater performance community. There is a strong focus on discovering new forms and expressions within musical contexts, which are neither beholden to nor inextricably separate from what had come before [1]. On the contrary, new forms in musical expression are often a response to what came before. This reactionary approach to novel musical methods has recently come to the forefront with the rise in remote and virtual forms of expression. Live music especially is in a current state of flux. According to Taylor et al, the "production and consumption of music's cultural meaning...exists and resonates within a given space, and its meanings are colored and shaped by that space" [2]. With live music relying so heavily on the physicality of the experience and the spaces in which it is experienced, exploring novel ways of musical consumption and experience are paramount. Developing a method in which these new forms of expression can exist not only as an alternative to traditional performances but as a new dialogue in it's own is one of my strongest intentions. Designing engaging sonic works which would utilize physiological sensing and carefully constructed musical structures which act responsively to the data input, these works could introduce engagement from musicians and audiences alike, regardless of their own musical knowledge or abilities. Developing this kind of flexible and responsive system for sonic expression could lead to new performative hierarchies and allow for new sonic communication.

1.3. *Sonic Vessels*

The core of my concept is a method which I call *Sonic Vessels*. In short, this approach involves the utilization and exploitation of presence in performative works. These works break free from the confines of location, time, and space to provide the most flexibility in expressive affect. This approach will allow for a more varied and affective method of live performance. As seen in Fig.1.3, this method incorporates sound objects, biofeedback, liveness, and the audience to coalesce into a cohesive performative and compositional structure.

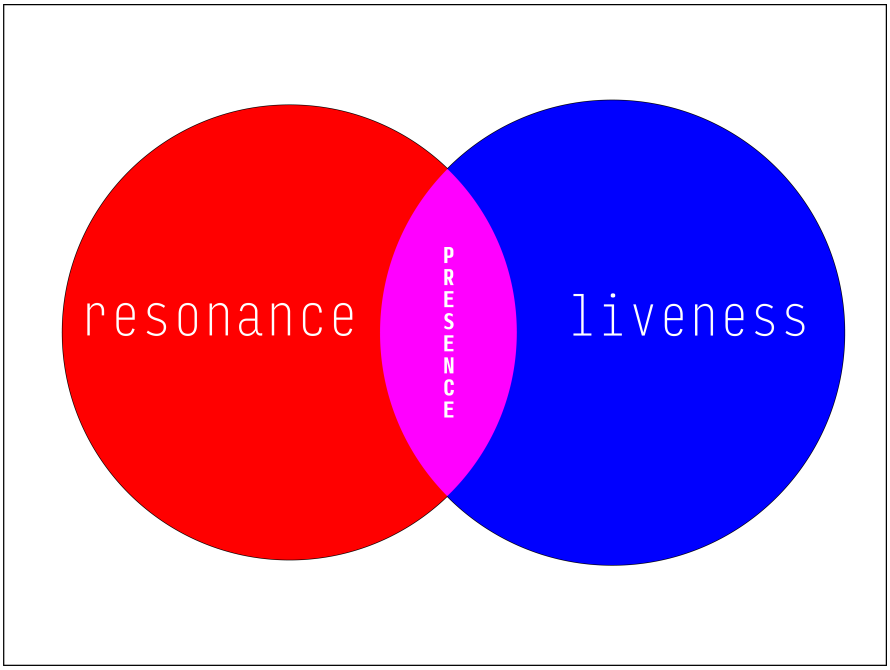

Figure 1.1 Resonance and Liveness

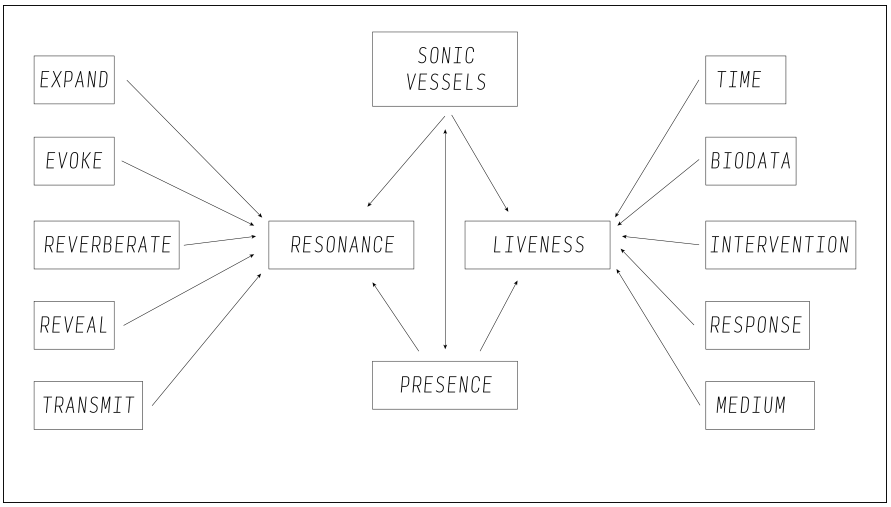

Figure 1.2 Diagram of Resonance + Liveness

The core structure of the *Sonic Vessels* concept consists of two main tenets as seen in Fig.1.2: *resonance* and *liveness*. "Expand, evoke, reverberate, reveal, transmit": these are the words first presented in the Shelter Press book *Spectres II: Resonances* [3]. These words, as I interpret them in the context of my own sonic works, carry a heavy meaning in terms of *resonance*. To ***expand*** the dialogue and reach of the music, to ***evoke*** the feeling of a performer beyond sounds, to ***reverberate*** throughout the "stage", to ***reveal*** some inner dialogue, to ***transmit*** expression beyond the traditional stage. In viewing *liveness*, a similar set of keywords represent this second tenet of the *Sonic Vessels* method. This *resonance* can be realized through ***time***, ***biodata***, ***intervention***, ***response***, and ***medium***. For each work I present in this method, I will discuss how unique combination of these two main tenets are utilized. When realizing this method, some kind of external musical artifact is used as the "vessel" for this externalized performer presence. Although I present no real firm restrictions on what kinds of external artifacts may be used, each work I will present will show a different artifact. When taking this external artifact into account, the intersection of *resonance* and *liveness* converge to present the perceived presence which is then brought to life so to speak through this artifact as seen in Fig.1.3.

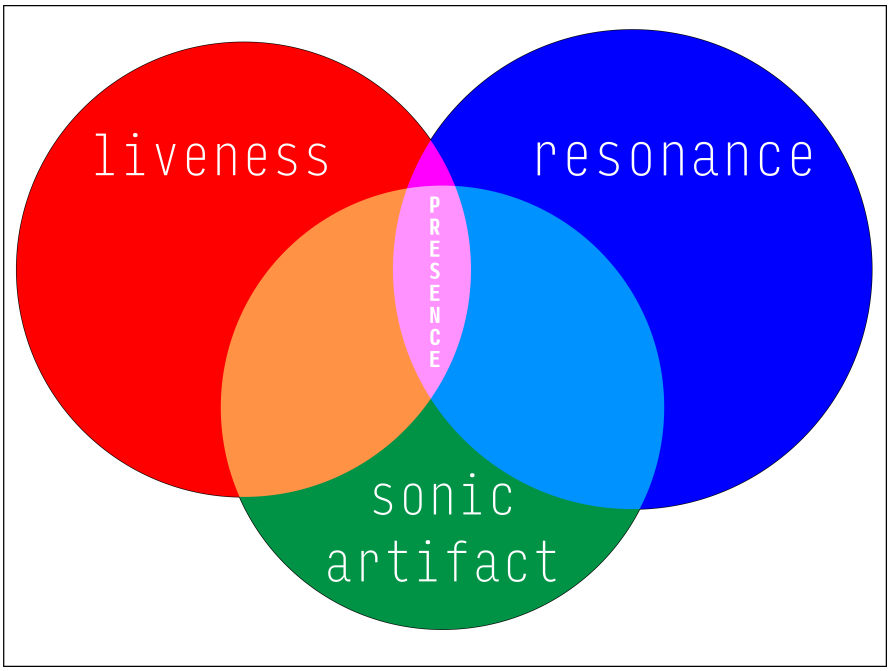

Figure 1.3 Resonance/Liveness/Artifacts in *Sonic Vessels*

A New Methodology for Embodied Sonic Expression

This thesis will explore my proposed methodology for developing a form of embodied sonic expression. This will consist of techniques and methods for presenting the presence of performers and/or composers into objects other that them i.e. a self-playing instrument, a sound-producing object, an inanimate object, the structure or form of the music itself, even an empty space. My goal is to provide a blueprint with which people can explore this idea on their own and justify the projects which I will present as a defense of my proposed methodology.

Achieving an approach of embodied sonic expression requires an investigation into the relationship between the performer and their sonic object i.e. instrument. Whether this is an acoustic instrument (tuba, violin, piano), an electronic instrument (synthesizer, laptop), or even a non-traditional music making device (wine glasses, plastic bucket, rocks), a certain level of familiarity between the user and the object is essential. Tanak and Donnarumma state that this interplay between the physicality of the instrument and the physical body engaging with it as "a cybernetic human-machine extended system" [4]. In this view, the human and the

instrument become one entity engaging in a corporeal and embodied dialogue. They also describe the performer who, once achieving a comfortable level of expertise in a particular instrument, can speak through their instrument, thereby relegating the instrument to a "vehicle through which the music speaks" [4].

1.4. Research Questions

For my thesis, I will present two main research questions which I will explore:

1. Can the use of "*sonic vessels*" convey a new sense of experience in performative works?

2. What new kinds of sonic and performative dialogues will come out of my proposed methodology?

For the first proposed question, I have developed a way in which sound can be used to convey the presence of a performer. This could also apply equally to the presence of the composer in the case that these are two separate people. While the argument that a performer's presence is inherently represented in their interpretation and execution of a written score, the separation of performer presence and sonic object/body is what affords a new kind of dynamic. When the performer's presence is allowed to exist as something separate from themselves, this embodiment can take on a multi-faceted existence. Although the direction and intervention is passively connected to the performer themselves, the direct control is not present is would be the case with a performer controlling their instrument. A saxophonist has direct control over their instrument as they breathe into the instrument, place their fingers on the keys, and direct this physical instrument to sonify their intentions. With an external means of sonification and gesture, there is a new degree of separation, thereby allowing an extension of oneself which can be conceptually and sonically viewed as it's own.

In order to convey this presence in some tangible form, the presence of the performers will be integrated into numerous stages of the performing works, including musical elements such as harmony, rhythm, dynamics, etc., as well as performative elements such as orchestrational and contrapuntal dialogues. This

perceived presence, or liveness, is a core element of the method. According to theorist Peggy Phelan, she relates live performance to the presence of the physical body [5]. While I do agree with this statement, utilizing the internal being, or physiological and physical state, of the performers would offer the ability to create expressive means which can be applied regardless of the physical presence of the performer. In other words, the perceived presence of the performers could be remotely presented as easily as in-person. This could also be applied using previously recorded data, therein allowing for a break from the linear nature of performance works i.e. a performer collaborating with their past presence.

For the second proposed question, this methodology will present a number of questions and concerns regarding the process of creating, implementing, and finally presenting these works. Much like how the inclusion of computers in orchestral music or the development of avatars in live music performances have produced new forms of expression, this methodology demands a revised viewpoint of the performer and composer in a fluid manner.

1.5. Research Structure

The approach to my research was based on several approaches including lab studies, the analysis of performer and audience data from live presentations, interviews with performers and composers, in-the-wild performances and installations, and lengthy explorations of the compositional and performative design which constitutes this overarching musical methodology.

Lab Studies and Data Analysis

To better understand how I can implement the presence of the performer or composer, an extensive lab study was conducted to establish certain characteristics of sound which would cause a greater affect on the listener. This lab study provided the ground truth for how the presence (physiological data, proximity, respiration rates, etc) would then influence the sonic qualities of the works. For most performances, physiological data was recorded from the performers and the audience members in order to analyze afterwards. This data analysis not only supported the impressions from the involved performers but also revealed additional validation

from the perspective of audience/performer correlation. This will be discussed in length in Chapter 4 as it relates to the project *Innermost Echoes* and in Chapter 5 as it relates to *Spectral Counterpoint*.

Qualitative Interviews

For each performance, interviews were conducted with the performers to gain a better understanding of how they perceived this *Sonic Vessels* implementation, how this method caused a change in their own performative approach, and how the overall experience differed from performances without this method. In addition to these performers, several professional performers, composers, and industry professionals were interviewed who had either experienced this method or have shown an interest in utilize it for their own works in the future. These interviews serve as a qualitative exploration of the method which relates to and is compared to the quantitative data analysis.

In-the-Wild Presentations

In order to fully develop this method, numerous live performances and gallery installations were presented which each focused on one or more aspect of *Sonic Vessels*. These implementations will be discussed further in Chapter 4 and Chapter 5. For each performance, the results were discussed and analyzed in order to better implement the proceeding events. In addition to these main implementations, there were a number of preliminary collaborative works which were used to further test and explore this method which you can find in the Appendix.

Evaluation Method

The evaluation of this proposed method will follow a combination of qualitative interviews with the performers and composers who are directly utilizing this method, artists who have been shown the method and have an interest in deploying it themselves, theoretical and conceptual discussions akin to traditional music compositional evaluation, and quantitative data analysis taken from user studies and performances. This kind of quantitative data analysis provided early research into the qualities of sound which proved to generate a response in the

listener, and will further reveal a ground truth in the implementation and give supporting validation for the qualitative interviews and responses from the participants. Typically, in performance-based music studies such as this, a great emphasis is given to qualitative interviews and questionnaires to gauge how the involved people responded to and deployed such a method. Furthermore, music can and should be seen as a flexible and personal experience for the listener and performer. While music can vary greatly depending on the genre, style, or presentation, these experiences can in many ways be evaluated based on their ability to bring people together in a social setting which can be shared together [6]. Therefore, I will present each work and discuss their social value in how they afford this kind of shared social experience, in both traditional and novel ways. With this, I intend on strengthening the qualitative evaluation with quantitative data analysis, thereby affording a multi-faceted view on the works being presented.

The structure of the analysis and overview of each presented main work will observe four main principles of the concept and how each main point was implemented or utilized in the work. These include:

1. Time-Domain: How these works are deployed chronologically. These performances can utilize the presence of the participants in real-time, from past occurrences, or even a mixture of the two.

2. Passive Presence: How the presence and *liveness* of the participants is utilized. In much of my work, I utilize physiological data, specifically EDA, HRV, and BPM. However, some works may utilize other means of presenting the presence such as respiration rate or spatial location. This also relates to the geographic location of the works. For instance, sometimes everyone involved is in the same room, while other implementations utilize remote possibilities.

3. Musical Artifact: A proposed object for sonification i.e. a *Sonic Vessel*. Taking the name of this thesis, these artifacts will be the driving force of sonification of the presence, location, and time of the participants being utilized. This may take the form of a physical object, a bespoke musical instrument, or an existing musical tool.

4. Performative Dialogue: The ways in which the performers or participants interact with the objects or settings being presented. This focused mainly on how the live musicians interact with these sonification objects but also refers to participants in a gallery setting or the objects themselves.

Below in Table 1.1 you will find an example of how these elements will be overviewed with each of the main implementations as they are discussed in Chapter 4 and Chapter 5.

Table 1.1 Conceptual Points in *Innermost Echoes*.

Conceptual Aspect	Usage in the Presented Work
Time-Domain	The performance is occurring in real-time.
Passive Presence	EDA, HRV, BPM of the performers.
Sonification Object	Robotic koto and Eurorack synthesizer
Performative Dialogue	Robotic koto responds to performer data and performers respond to the sonification.

So far, I have presented *Innermost Echoes*, an embodied performance work which utilizes a robotic koto and Eurorack synthesizers to sonify the physiological data of the performers, several times: once at our Roppongi exhibit on June 24-26, a second time at the KMD Forum, as part of the Music track for the New Interfaces for Musical Expression (NIME) conference in May 2023, and at the live house Bar Transit in Hiyoshi, Japan. Another in-the-wild presentation of *Sonic Vessels* was *Phantom Undulations*, which was presented as a demo at the Augmented Humans conference in March 2023 in Glasgow, Scotland. In this work, my physiological data was transmitted to Scotland and allowed for the audience's data to join mine in a remote counterpoint. *Corporeal Counterpoint* was another live performance which took place in April 2023 and featured performance artist and researcher Stelarc. In this work, the performer's live data was sonified through a Eurorack synthesier setup and a Pure Data granular synthesizer developed by Geist PhD student Imsael Rasa, in which the physical location of the performer was used to spatialize the resulting sonic explorations. These works will be discussed in greater detail in Chapter 4 and Chapter 5. Finally, a cumulative work titled *Spectral Counterpoint* was presented at Miraikan on November 10th and 13th

which explores my concept in greater detail and specificity. This work involves the remote presence of several participants whose data offers real-time control and content for a live performance. In many ways, this work was a culmination of my conceptual framework and began a further study on musical temperament which fluctuates along with live data. This work will be discussed in greater detail in Chapter 5.

1.6. Contributions

By the end of this thesis, I will have presented my concept of *Sonic Vessels*: a framework for exploiting the presence of the performer and the utilization of presence detection in a novel compositional dialogue. In order to justify and evaluate this as a viable method for exploring and presenting new forms of musical expression, the research will be roughly divided into two main modules, which focus on the performative aspects and the compositional aspects respectively. These two modules do in fact have a substantial amount of crossover with each other, but diving it to a certain extent will provide a clearer and more concise approach to taking on the larger methodological framework.

Module I: Liveness as an Expressive and Embodied Communication

Liveness, or the idea that something has life and the implications thereof, is a field of research which has a tremendous impact and validity in my proposed methodology. In my method, the presence of the performers is shown through what I call *Sonic Vessels*, or something that exists which conveys this performer's presence. Taking this as a guiding principle, performative works can be derived which can challenge existing hierarchies in performative works and introduce new dialogues between performers and a number of other participants (composers, audience members, physical objects, virtual/non-visible entities, etc.). Presenting this kind of novel sonification and presence-suggesting method can lead to many new directions in performative discourse for performers, composers, and audiences alike.

Module II: New Compositional Methods

As with most new directions in music performance and composition, careful attention must be given to how the structures, tonalities, and expressions within said music will inherently change. This is certainly the case with my method. When the presence of the performer and/or composer is given it's own means of sonification and performative gestures, this must change how we as composers approach this kind of situation. The presence that is being utilized, whether through physiological sensing, proximity, spatial location, or any other means, may not inherently be something that is actively controlled. In fact, most of the forms of presence-indication which I propose present a passive engagement. By this, I mean that the performers or composers are not strictly in control of this input. Therefore, it is a passive indication which is then given a more active influence on the works themselves. By structuring it in this way, the ways in which composers navigate this method must honor this and allow for a certain degree of flexibility.

Position Within Existing Methodologies

This methodology which I am presenting will contribute a unique consideration for the passive presence of the performers and composers while also allowing for great flexibility in the implementation. Although biomusic and liveness are already existing concepts within the larger artistic community, this combined method of performative, compositional, and perceptual presence as it exists within sonic works provides a multi-modal approach that will provide new forms of expression within predominately musical frameworks.

Foundational Elements

I also plan on releasing the full Max/MSP framework which I am using to develop my work in addition to this thesis and related supplemental materials publicly so that other composers, performers, researchers, and media artists can take my proposed methodology and make their own contributions to it or in response to it. This kind of exchange and challenge of ideas is crucial to musical discourse. It is my hope that other artists will use my work to create their own expressions,

to critique my work, and to guide them towards a similar journey of discovery into the overall concept of "sonic vessels". As with virtually any new concepts within performing arts, these structures must be taken and used by various artists and researchers in order to strengthen their impact and give them a unique space within the existing canon.

1.7. Thesis Outline

This thesis consists of seven chapters, as detailed below. Here I present a brief overview of each section, their relevance to the larger concept, and how each section connects to the others.

Chapter 1: Introduction

This is a preface to my thesis work. In here, I discuss my motivation for how I cam e to create this *Sonic Vessels* methodology, my background as a performer and composer, the purpose of this work and how it is framed within the existing canon of performance practices, the initial definition of *Sonic Vessels*, the research questions I aim to solve, how I have structured my studies, the methods in which I intend to validate my method, and the contributions which my method will give to the greater performative community and beyond.

Chapter 2: Related Works

Here I will give an overview of existing works past and present, how these works contribute as a whole to the inspiration and implementation of my method, how these related works are positioned within the larger canon of performative and compositional works, how they relate to one another, and how my method will work to extend these principles and provide a foundation for the extended works which are missing in them.

Chapter 3: Concept

In this section, I will lay out my *Sonic Vessels* concept. This will involve an overview of the method, the main hallmarks of the method which include:

1. Time-Domain: The ways in which time and location play a factor in the presentation of these works. This will include past and present presence-indicators, the location of the performative elements, and how the timing affects the perception of the works from the performer and audience perspectives. The concept of "space-time" as it relates to live performance is one of the core driving factors of this approach. When the past, present, and future experiences of a work are combined into one, new experiential possibilities are allowed to exist and connect audiences and performers from different times and places.

2. Passive Presence: The ways in which the presence, or *liveness*, of the performers and participants is shown. This will include physiological data acquisition and implementation, physical elements such as respiration and proximity, and how and why sonification objects are presented.

3. Musical Artifacts: The ways in which objects will sonify the presence and responses of the participants and/or performers. These include bespoke musical instruments such as the robotic koto, existing musical instruments such as the Eurorack synthesizer, and software elements such as Max/MSP.

4. Performative Dialogue: The ways in which the performers will interact with and respond to the elements listed above. These will include elements of performative responses such as improvisation and the deployment of musical gestures such as rhythm, pitch selection, dynamics, and other musical elements.

Chapter 4: Momentary Vessels

This chapter will cover the main presented work within Momentary Vessels, a sub-category of the larger Sonic Vessels methodology. This category of works focuses on real-time and in-person performances which focus on "the here and now". In short, these works are about our current presence and how that current presence becomes its own presence through sonification and adaptive performative intervention.

Innermost Echoes is work utilizes a bespoke robotic koto along with Eurorack synthesizers to sonify the real-time presence of the performers. The aim of this

work is to use this real-time presence indicator as it's own musical and performative voice, which is then improvised with alongside the human performers. Creating this real-time performative dialogue and presence sonification is the main aim of this work. This performance/installation work serves as the main Momentary Vessels work.

Chapter 5: Transient Vessels

This chapter will explore the second category of Sonic Vessels, which focuses on works which exist outside of in-person and in-time methods. This category challenges what it really means to perform live in the context of place and time by combining different geolocations and places within time itself, such as performances that exist from the past and present, and which contribute to future performers at the same time. There were two main Transient Vessels works which will be discussed.

Phantom Undulations: This installation work utilizes the recorded presence of the composer which is then presented to participants whose own data can interact with and influence the recorded composer data. In this sense, this work seeks to create a distance between past and present sonification methods and encourage a dialogue between the two.

Spectral Counterpoint: This final work encompasses many of the aspects of the *Sonic Vessels* method by utilizing real-time participant data, the interpretation of that data by the live performer, create a connection between past and present performances, and sonification methods i.e. a *Sonic Vessel* in the Eurorack synthesizer and Max/MSP.

Chapter 6: Discussion

In this chapter, I will discuss the implications of the evaluation and how it frames *Sonic Vessels* as a novel performative methodology. This will include discussions on specific sonic aspects of the works as they relate to the indication of presence, how the findings reveal concrete results that imply the success of *Sonic Vessels* as a means for creating new experiences, and how these projects connect to one another as a larger conceptual framework. Next I will present limitations of my current practice, how these limitations can be addressed in the future, and go

into detail on the future works which I will present to provide a continuation of my presented method. It will include a continuation of several presented works including *Innermost Echoes* and *Spectral Counterpoint*, in addition to new works such as *Ephemeral Temperament*. Finally, I will discuss the social impact of my methodology and how it can be positioned both within and beyond the current musical landscape.

Chapter 7: Conclusion

Finally, I will close with my final thoughts on what I have learned from developing this method and what the future holds in store for this research journey.

Chapter 2
Literature Review

The background inspiration for my thesis is rooted in the history and development of novel technologies and their incorporation into contemporary sonic arts. I will investigate and present the history of the use of computers and electronics in 20th century music, the development of avatar performers and virtual performances, the research and practice of *liveness* in contemporary works, conversational aspects of sound-based expression, the effects of sonic immersion from a physiological and philosophical viewpoint, and the use of physiological sensing as an expressive tool. Furthermore, there will be a lengthy discussion on framing how these previous works have all contributed to the development of the vision of my research.

Many new and novel technologies have been adopted by contemporary composers and sound artists, including the *Musique Concrète* movement of the 1940s, the *elektronische Musik* which followed shortly in the 1950s, the inclusion of computers in contemporary classical music, as well as the use of new technologies by popular artists such as Yellow Magic Orchestra, Kraftwerk, and Björk. One of the most common threads among these adoptions of new technologies is a shift in the compositional and performative, as seen in such works as *mild und leise*, the first computer music song composed by Paul Lansky as an adaptation of the Richard Wagner piece. In all, the inclusion of new technologies and the dynamic between composers and technologists is one of mutual importance. As described by acclaimed electronic music composer Herbert Brün, the relationship between composers and technologists shares a common thread in which they "both continuously design, construct, create, and change languages of all kinds, in order to store and transmit the thoughts or images they had in mind" [7].

2.1. Current State of Technology-Based Performative Works

The current state of technology-based or multi-modal performance works is extremely strong. One artist whose work continually challenges the possibilities of technology and music is that of Björk, with her Cornucopia multimedia performance work touring the world and utilizing a number of novel technologies including a collaboration with engineering firm Arup [8]. Holly Herndon is also pushing the possibilities of novel technological implementation into sonic works. Her album Proto featured an AI software named Spawn which she and Mat Dryhurst developed [9]. She has discussed that her intention with this work was to make the use of AI technology more humanizing and allow for this technology to appreciate the human component as opposed to replacing them [10]. Another strong recent work is that of the James Blake and Endel collaboration titled Wind Down. This ambient album, meant to promote sleep, involved musician/composer/producer James Blake working alongside generative music app company Endel to create these soundscapes [11]. One of the major things which I see running through all of these current prominent works is the intention of presenting and incorporating the human elements into these new and digital technologies. Far from the images of technology taking over the human world, these artists are creating works which provide a new relationship between technology and artists: one in which neither is taking precedence over the other, but instead an approach which creates a hybrid dialogue between the two.

2.2. Performance as Dialogue

Viewing music and performance as a dialogue is a frequently discussed and supported belief [12] [13] [14] [15]. For my work, these live performances are indeed a form of dialogue between individuals. This could take shape as performer to audience, performer to performer, or even one individual to a sonic object. Regardless of the directionality and dynamic between the people or objects involved, this dialogue provides the backbone of the artistic expression myself and countless other artists form our works upon.

2.2.1 Early Music

Much of the iterative compositional explorations which I use to discover the tonalities, gestures, and harmonic discourses throughout my works are heavily inspired by early music. More specifically, medieval music styles including Ars Nova and Organum. Ars Nova, which was occurring predominately in France in the 1300s, saw the extended use of what has been referred to as "directed progressions", or a sequence of an imperfect sonority followed by a perfect sonority [16]. This utilization of imperfect vs perfect sonorities was a significant step forward in the use of harmonies and tendencies as an expressive tool in music composition. Organum, a method of music composition which dates back to the 10th century, saw the use of cantus firmus alongside modal rhythmic materials, a revolutionary combination realized by Léonin and Pérotin [17]. This combination of a steady cantus firmus along with more active rhythmic lines would lead to a number of future compositional developments which sought to explore new musical expressions while still honoring the previous foundational works which came before. This acknowledgement and appreciation for what came before while seeking some new kind of musical language is a constant in my own work.

2.2.2 Improvisational Music

As was stated in the previous chapter, my early musical experiences were rooted firmly in the jazz tradition. One of the hallmarks of jazz music is the use of improvisation. This use of improvisation can be seen as a way of developing a performer's own musical vocabulary [18].

While improvisation in jazz music has it's own place within musical history, the use of improvisation has been developed and implemented for many hundreds of years. Since the development of some of the earliest music including *tonoi* from Greece and *chant* music from early Western liturgy, improvisation has been a vital part in the development of musical languages and dialogues [19]. In fact, early instrumental music would often use a score but in fact relied heavily on the improvisation of the performers [20]. This is also seen in the "cadenza", in which a performer is to improvise a segment of music by themselves [21]. One crucial aspect of musical improvisation is the simple act of making the decision to perform

non-written gestures. While there are varying degrees of musical improvisation, ranging from total free improvisational works such as those championed by artists like Sun Ra and the Art Ensemble of Chicago to the more loosely structured improvisational elements of contemporary orchestral composers, such as Olivier Messiaen and György Ligeti, improvisation has had a large part in developing new musical ideas. This could in part be due to the concept of *perceptual agency*, or "the conscious focusing of sensory attention that can yield differing experiences of the same event" [22] as defined by Ingrid Monson.

In her essay "Essence of Improvisation", vocalist and composer Joan la Barbara describes the essence of improvisation as a "pure thought in sound" [23]. She goes on to state that "it unfolds and I control, follow, coax, permit, listen, burst forward, soothe, wait, watch learn, shape patiently then intensify" [23]. For me, this truly captures, as she describes, the "essence" of improvisational language and gesture. It is not something that we quantify or calculate in any traditional sense (although traditions are many within the loose construct of improvisational works). It is something far more visceral and corporeal, while existing in many ways as an internal mechanism.

One core tenet of musical improvisation is that of the music-making process. Improvisation is not a random occurrence, but instead can be viewed as a more spontaneous method of making music [24]. It is this spontaneity which can afford the opportunity to create new works in real-time without the pressures or second-guessing that might occur when obsessing over the musical language, as is the case with my own work from time to time. Far too often I find myself struggling with too much time to overthink on a particular passage or sound quality. This unfortunately leads to numerous delays in completing a composition or recording. When improvisation is made to be a core element of the work of my own, it often times leads to a more fluid path towards completion. Instead of spending too much time on overthinking, I focus more on what happened in the moment and accept it for what it is, warts and all.

The *Sonic Vessels* method of performance and composition will challenge existing performance methodology by using the physiology of the performer and interpretation of this data as a new communicative element. I do not intend on debating the status of music as a language because I do not find it a meaning-

ful debate. However, my work will present methods for expanding upon current musical dialogues by allowing for a more inherently direct form of communication (via biofeedback) to be applied and utilized in sonic works.

2.2.3 Performative Hierarchies in Music

As I began to develop my method, I found early on that the roles that each of us play in these ensembles was not something I was used to. When the passive presence of a performer or group of performers is represented as an active musical component, it inherently changed how we saw ourselves in the ensemble. This will be discussed in further detail in Chapter 3, Chapter 4 and Chapter 5.

In most forms of music, there exist certain hierarchies which are often quite unique to different genres. For example, within the context of orchestral music, the conductor can be seen as "gatekeepers of power and knowledge" [25]. The musical score itself also gives quite a lot of power and control to the composer over the performers and even the conductor [25]. As you continue down the line of so-called power dynamics in orchestral settings, you also have the principal of the orchestra, oftentimes as the lead violinist. The principal is responsible for giving the central tuning pitch for the entire ensemble to tune against. Throughout history, this central tuning pitch has been in flux and today continues to see some variations. For example, in the Baroque period, the tuning pitch ranged from A415 to A456 [26]. In Paris during the late 19th century, A435 would become the prominent tuning pitch [27]. Although these variations do in fact present differing pitch-based affects, the general consensus is to align with A440 with most contemporary orchestras in the United States and abroad [26].

In terms of hierarchies, the violinist serving as the principal is due to the strings being the primary group of instruments in the orchestra, followed by the winds and brass sections [28]. While this is not necessarily always the case in modern orchestras, the tradition still stands.

Within popular music, such as jazz and pop music, similar yet unique hierarchies can arise. For instance, in jazz ensembles you may also have a conductor. One glaring difference here is that typically a jazz ensemble will have more flexibility in terms of improvisational performances. The jazz conductor's role is still quite similar to that of an orchestral conductor, having a sense of shared leadership

between themselves and the performers [29]. Pop music also tends to have it's own particular hierarchies. The lead singer of a pop or rock ensemble is generally given the most attention. This may be due in large part to the fact that they are the one who is typically delivering the lyrical content which can give huge influence over the interpretation and experience of the audience. While this role may not exactly be that of a conductor, there is certainly a degree of control and direction that a singer is giving.

Conduction, or the use of unique physical and visual gestures as a means of guiding a performance, was developed in large part by Lawrence D. "Butch" Morris. Presented as a mixture of traditional conducting methods and visual gestures, this approach allow the performers to interpret the movements of the conductor as a novel guide for interpreting the material and giving meaning to these gestures [30]. This conduction method allows for an enhanced form of dialogue between performers, thereby allowing for this dialogue to contribute to the evolution of the music [30].

The method of "soundpainting" has some similarities to conduction, with some key differences between the two. Whereas conduction generally focuses on the dialogues between conductors and performers, soundpainting is posited as a method which can allow the increased skill and comfortability with improvised music [31]. Although conduction can also provide this foundation for improved improvisation and ensemble playing, the soundpainting approach is in itself developed as a means for increasing this skillset and affords a broader range of application, such as within dance and performance art [32].

2.2.4 Physicality as a Means of Expression and Performance

When examining what truly makes a sound "live", it is important to question what aspects can contribute to this sense of being in an abstract thing such as sound. While sound does not in itself have a physical structure beyond air pressure moving through the air or the resonant vibrations which it can cause, the implication or interpretation of the physical tangible being can afford the listener a means of experiencing the physicality and life of the sound. One example of sound's relation

to air pressure is shown in the field of cymatics, in which the vibrations of sound can be seen through another medium such as water or sand [33]. By using these other mediums as a way of seeing the invisible, the physical existence of sound can be made visible. This visual representation has been utilized in many works, such as Meara O'Reilly's visualizations for Björk's *Biophilia* live tour [34].

The life or liveness of invisible sound can in many ways mirror most any other organic living thing, such as a human, animal, or plant structure. It can breathe, it can feel pain, it can be broken, and it can die. What does it mean for a sound to breathe? To become broken? To die? As stated by Nomi Epstein, "fragility...offers a sonic experience where both the possibility of stability and the possibility of its obliteration have been demonstrated" [35].

The physicality of a performer can be used effectively as a means for self-expression. One such example is found in "The Godfather of Punk" Iggy Pop. Born James Newell Osterberg Jr., he is one of the most enduring and prolific performers within the punk and rock music genres. The persona which he developed as Iggy Pop relied in many ways on the visceral, confrontational, and at times outwardly violent stage presence he gives forward. This aggressive performative presence is as much reliant on the audience and the physicality of the performer as it is on the music itself. Another performer whose physicality is inherently tied to their stage presence is that of Henry Rollins, both a solo artist and frontman of Black Flag. His shows were known for becoming quite physical and violent, with Rollins at times directly confronting audience members he saw as antithetical to his/their political and/or social values. This inherent physicality became intimately ingrained within many musical works and groups who would follow in this approach, such as The Dillinger Escape Plan. While their music took on a much more technically focused and widely inspired approach, the core elements of physicality and the human body as a performative tool are consistent with these early pioneers in physical expression in heavy musics.

2.3. Technology as Expression

The utilization of technology as a form of expression has been a large part of the creative world for several centuries now. This can be seen in various applications

in music, film, photography, landscaping, architecture, and virtually any form. In my work, the use of technology as a form of sonic expression is a highly important facet of the overall concept of this thesis. Here I will discuss how technology as it is used in expression has shaped the work I present.

2.3.1 Automatic and Mechanical Music

Throughout history, there have been many instances of automatic or mechanical sound producing instruments. One of the earliest and most well known is that of the Aeolian Harp. This instrument, a wooden box with strings on top of it, is actuated by the wind. Some of the earliest writings about it were from Athanasius Kircher in his book *Musurgia Universalis* [36]. The manner in which this instrument would be actuated by a natural phenomenon such as the wind almost places nature itself as the performer. This instrument, along with similar instruments such as the monochord, use strings to demonstrate and exploit harmonic scales and ratios which have a deep connection to early works from Pythagoras, who is credited as a pioneer is the study of mathematics in relation to musical systems [37]. Another example of these mechanical musical objects is attributed to the 12th century inventor Ismail al-Jazari, who created a boat with four automatic instruments on it [38]. This method of applying a mechanical musical device to a utility such as a boat displays an intriguing sense of wonder and curiosity.

2.3.2 Musique Concrète and *elektronische Musik*

One of the predominately conceptual elements of this exploration into sound and presence affect has been that of time and memory. This all began in full with the installation work *Ephemeral Counterpoint* which will be discussed in Chapter 3. In this installation work, old recording mediums such as 1/4" tape, cassette tape, and VHS were utilized to represent the decaying nature of my own childhood memories. This contrast between how I remember these events and how they were presented in this gallery generated a renewed interest in how recorded media can be used not only as a documentation method but also as an expressive tool. This approach was heavily popularized and explored in the field of sonic works known as Musique Concrète.

One of the earliest figures in the development of what would become known as Musique Concrète was Halim El-Dabh. His work dating to around 1944 involved the experimentation of wire recorders and the exploration of finding microsounds within ceremonial practices [39]. Around 1948, a new revolution in experimental and stage music was developed by composer Pierre Schaeffer, a few years after these initial explorations by El-Dabh. *Musique Concrète*, or "Concrete Music", was a style of composition and performance which relied on recorded sounds as the performative material itself. The name is derived from the concept of "music made with fixed sounds, unconcerned with the origin of the sounds it uses" [40]. Schaeffer and his colleagues formed the Studio d'Essai de la Radiodiffusion Nationale, which served as a leading voice in the Resistance movement in Paris around the time of WWII [41]. Much of the work they did involved the experimentation and exploitation of recorded media. This began with recording sounds onto 78 rpm records and quickly shifted towards magnetic tape recorders, which became more accessible in this time. The work was somewhat focused on exploring how to take "concrete" sounds and record them in an expressive way. For example, to explore "a material/construction dialectic which is resolved by the introduction of two extraneous elements: a new musical training and the tape performance" [42]. This practice of utilizing the modern technologies of the time and intertwining it's capabilities and limitations into the very fabric of the compositional and performative process established a strong sense of experimentalism in the modern music of its time and led to the formation of many subsequent genres and stylistic practices including industrial, granular, microsound, plunderphonics, and hip-hop music.

Utilizing predominately analog synthesis in my works is a mostly aesthetic and conceptual choice. This is due to two main reasons. First, I have found that as a performer I respond more naturally to the sometimes unpredictable nature of analog synthesizers and the physicality of these modules. When responding to and performing alongside the perceived presence of other performers (especially when using physiological data), physically interacting with the endless sea of knobs, cables, and switches that my Eurorack synthesizer system offers is performatively validating. Secondly, on a more conceptual level, I find that having a human presence sonified through a physical series of transistors, diodes, and resistors

better exemplifies this human presence versus a strictly or predominately digital sonification method. This is a mostly aesthetic choice which I have made and I would be remiss if I did not dive into the history of electronic music which paved the way for my own explorations.

In 1952, German composer and theorist Karlheinz Stockhausen worked at Pierre Schaeffer's studio before moving to Cologne. Following his settling in Cologne at Studio für elektronische Musik des Westdeutschen Rundfunks, he began work within the movement founded by Herbert Eimert and others which would become known as elektronische Musik, or "Electronic Music" [43]. While this new compositional practice shared many of the same ideals as Musique Concrète, one of the biggest divergences was the push to create works which were solely electronic in origin. Whereas Musique Concrète strived to utilize recorded sounds as expressive gestures, Electronic Music utilized things such as oscillators. Herbert Eimert stated in 1956 that electronic music is comprised of electronically produced sounds, exists only on recorded tape, and can only be realized through a loudspeaker system [44]. While this statement may seem a bit extreme and outdated in our current time, it was a rather impactful statement at the time. This is the biggest distinction between concrete music (music made from acoustic sounds) and electronic music (music made from electronic sounds). This distinction is still being utilized today and continues to offer a wide array of exploratory possibilities in modern music.

2.3.3 Immersion in Sonic Works

When deploying experiences which are intended to cause a strong affect in the listener, especially when the liveness of other performers is a central component, the use of sonic immersion has been an area which has offered new insights for me into how the overall sound field can be perceived. While this is a bit more difficult to undertake when acoustic instruments and an audience are involved, it has undoubtedly had an effect on my work.

The sounds and acoustics of a space have a direct impact on the way we perceive the sonic occurrences within them. In her book *The soundscape of modernity: architectural acoustics and the culture of listening in America, 1900-1933*, Emily Thompson states that "reverberation connected sound and space through the ele-

ment of time" [45]. This direct connection between a physical place, the materials used to construct it, and the sounds which exist within it are all inherently tied to one another the create the resulting experience. With current technologies in sound spatialization and artificial recreations of spatial audio settings, the sounds and the spaces can exist separately from one another and be addressed specifically to suit the needs or wants of the people constructing the given experience [46]. This ability to specifically create the acoustic and perceptually spatial environments we wish allows for a much broader and flexible control over the spatial audio experience.

Sonic immersion, or the feeling of being surrounded or engulfed within a sound field, is applicable and utilized in a number of fields and practices. Whether it is in urban development [47], installation works [48], or video games [49], the use of immersive sound can lay the foundation for experiences across a wide variety of intentions and disciplines. Contrary to what some (myself included) may believe initially, sonic immersion does not necessarily rely on many channels of audio or even the spreading of sound throughout an entire space. What is to be considered as sonic immersion could simply be a means of eliciting a strong engagement level from a listening body through the sonic content being provided. In other words, I would posit that the sound itself is inherently crucial for obtaining the desired immersive feeling.

When composing for acoustic instruments, the placement of performers on the stage contributes greatly to the perceived spatialization of the produced sound. It has been posited that hearing music in and of itself is to be considered spatial, simply based on the nature of the human auditory system [50]. Orchestral music and music specifically written for concert halls utilizes the very nature of the space in which it is performed, sometimes unintentionally. Composer Anton Webern cited the specific needs of the space in which his work *Pieces for Orchestra op. 10* should be performed. In it, he suggests that these chamber works should not be performed in a large concert hall, which would render some of the subtle characteristics to go unheard or not properly perceived [51]. This utilization of physical space as a spatial domain takes into account the acoustics of the performance space while also addressing the typical placement of instrumentalists on the stage itself. Defining the exact meaning of the term "spatialization" when referring to

acoustic music can be difficult. Maria Harley states that "the distinction between works with quasi-spatial structure (unusual seating plans, movement, ensemble dispersion) and latent quasi-spatial structure (standard seating plans)" can be troublesome [52]. Examining this difficulty in providing a clear definition of spatial audio and structure, composers in the 1950s and beyond began to experiment more with the musical content as a means for spatial perception.

The utilization of physical performance spaces and the audience/performer configuration can lead to many different stylistic and interpretive nuances which a composer can exploit. For instance, the vocal work *e s p a* _ by Yannick Guédon takes advantage of both the physical placement of the performers and the strict use of a single repeating pitch to emphasize the individuality of each performer. Contrary to what one may expect from numerous singers producing the same pitch, he posits that the act of repeating the same pitch actually emphasizes the different nuanced characteristics of each singer [53].

2.3.4 Sonic Works as Dialogue

Coming from a strong background in jazz music, much focus was put on how we communicate with each other during live performances. Although it is not completely agreed upon in music circles, I would personally state that this kind of musical discourse is in fact some kind of dialogue. This idea of sound as a dialogue runs through the *Sonic Vessels* method.

In musical performances, drifting away from or deviating from the written music can provide a dialogue or communication between the artist and the audience [54]. This communication does not necessarily have to consist of any speech or directness. Benson et al state that "dialogue remains a powerful element in teaching and learning as well as in music" [12]. In fact, viewing and interpreting musical gestures as dialogue has been a staple in some music genres including jazz and early church music. For instance, in interviews conducted in the early 90s, American psychologist R. Keith Sawyer received a rather revelatory response from a jazz performer discussing the conversational aspects of his music. The musician stated that "when I do it, I'd find that there are these things coming out of myself, which I didn't even know were there" [55]. Furthermore, in many cultures there are long standing traditions of musical dialogue and communication. One

such example is early Christian music, which used service music to better enable communication in the liturgy [56].

There has been much debate on whether or not music or sound can be seen as a language. In their article *Comparison Between Language and Music*, Besson et al state that "both music and language rely on intentionality" [57]. This intentionality is a core component of virtually all forms of musical performance [58] [59]. The intentions of the performer, composer, and even audience are greatly intertwined to create a collaborative experience [60]. Two main topics I will discuss within the context of musical dialogue are improvisational music and the hierarchies found within musical ensembles.

2.3.5 Robotic Musical Performance

One of the earliest endeavors into my study of sonic affect centered on the use of robotics as a means of actuating a musical object without the direct physical intervention of the performer. This performative embodiment of an external performer provides a strong correlation between a person and their perceived presence via sonification and performative gestures. While the use of robotics in musical works has become much more prevalent in recent decades, an early example of robotic musical expression was the introduction of the Player Piano, a piano which was capable of performing without a physical performer via punch cards to control weaving patterns in fabric [61]. Further advancements and novel applications in robotic musical works have continued to come to pass, with some ensembles or artists whose is specifically focused on this multi-modal approach. One such artist is the group Captured By Robots. This ensemble, led by inventor and frontman Jay Vance, consists of various configurations of handmade robotic performers who utilize bespoke versions of typically recognizable instruments (drums, guitars, bass, horns). There have also been some fascinating uses of robotics in contemporary classical and modern music. One of the pioneers in recent robotic musical instrument design is Dr. Godfried-Willem Raes. Through his Logos Foundation, many innovative developments in robotic instrument design and implementation have been created. Electronic artist Aphex Twin has utilized several of these custom-built robotic instruments for his works which can be heard on his recordings *Drukqs*, *Syro*, and *Computer Controlled Musical Instrument Pt.1.* "Snar_2"

is a snare drum outfitted with thirteen internal small beaters and two solenoid-driven drum sticks on the outside. and "Hat". It is controlled via MIDI for the drum stick control as well as additional LED lighting. Another instrument developed by Logos Foundation for Aphex Twin is "HAT", which was designed to facilitate the striking of any object which is tightly clamped to it. It consists of 35 beaters of six different sizes, allowing for a much wider and flexible application. Much like the previous instrument, it is controlled via MIDI protocol.

Another large-scale work which utilized the use of robotics in modern music was that of Björk's *Biophilia*. Hailed as the first app album, it was a wide ranging project which included a fully functioning interactive app suite, several bespoke musical instruments, and educational workshops. Much of the thematic material for this album dealt with human's connection to and collaboration with nature, music, and technology. This concept was ingrained within not only the composition of the music but also in the approach of utilizing technology and nature into the very instruments and tools used to realize the album. With the robotic musical instruments, Björk collaborated with several instrument makers including Björgvin Tómasson, Matt Nolan, and Henry Dagg. These instruments included a Tesla Coil bass synthesizer, the "gameleste" (a hybrid gamelan celeste), the sharpsichord (a large pin-barrel harp), and a "gravity harp" (pendulum harp-devices which move at the speed of the Earth's rotation). As stated in an interview with Jason Richards for The Atlantic, she felt that the nature of these bespoke instruments changed how she approached her composition process, going as far as to have a customized interface made for her to notate and develop these ideas [62]. This fusion of nature, technology, and music also had a direct impact on the composition process itself. Instead of attempting to fit traditional music into non-traditional means, the music explored much more uncommon time signatures and forms, such as 17/8 time signatures.

Captured by Robots is a one-man metal band featuring singer Jay "JBOT" Vance and his band of robotic musicians. Featuring robots such as GTRBOT666 and DRMBOT 0110, this group challenges the meaning of live performance and often incorporates a deep lore surrounding the live human performer (JBOT) being enslaved by these robotic musicians . While the initial inspiration of this group was born out of a desire to get away from other people [63], this work

presents robotics as a means for presenting a unique form of liveness and musical performance which is on the one hand reliant on the programmer of the robots (JBOT) and on the other hand presents these creations as autonomous beings performing alongside their creator. In some ways similar to this approach yet in many ways quite different, the work of developer/educator Ajay Kapur has moved forward the possibilities of robotic musical performance systems. The "Machine Lab" at CalArts is a studio and workspace which houses numerous robotic musical instruments, including a piano, marimba, and numerous percussive objects. This was shown extensively in his work with The Machine Orchestra, which utilized seven robotic instruments alongside human performers [64]. The combination of human performers and robotically-controlled musical instruments provides a flexibility and alternate performative path which has been deeply influential on my own work.

In this thesis work, we developed a bespoke robotic koto which will be discussed further in Chapter 4. This instrument is directly tied to our physiology, but still afforded enough freedom to express things which we do not program directly. This is where I wish to contribute in the furthering of robotic musical performances: to present a sonic object which is robotically controlled but whose input is dynamic and directly tied to the presence of the other performers. by exploring this, I wish to expand the current accessibility and repertoire of robotic musical performances.

2.4. Presence as Performance

When thinking about a live performance, presence is certainly something that will come to mind. This could mean the presence of a live performer, the presence of the audience, the relation between audience and performer, the presence of some kind of autonomous sonic object, the list could go on and on. One core aspect of my presented work is to utilize what I refer to as passive presence. This is typically observed through physiological sensing or physical means of detecting one's presence such as respiration or proximity. This passive presence is not something that can actively be controlled by a person, but rather offers a tangible stream of data which is exclusively attached to the person. By taking this presence as a means of expression, it can then become an integral part of the performance

itself, thereby allowing for unlimited unique presentations.

2.4.1 Physiological Sensing and Artistic Expression

One of the principle methods of conveying the presence or liveness of a performer in my method is done via physiological sensing acquisition. I have had the luxury of constant collaboration with two post-doc researchers who developed a physiological sensing acquisition platform which was used in most of my works. This kind of sensing acquisition provides a concise method of gathering the passive presence of the performers while allowing them to rather freely perform without placing too much concern or thought into the connected devices. This also allows for the data that is received to be something that is out of their hands so to speak. In other words, the presence which is being gathered from them is not intentional on their part but an essential part of their being.

Novel applications of physiological sensing hardware and software applications have been utilized effectively in the context of musical expression. For instance, EEG (electroencephalogram) headsets have seen a variety of applications within musical expression and appreciation. One such application utilized EEG data to play music based on the current state of the user [65]. *PsychDome* is another work in which an EEG headset is utilized to induce or encourage a sense of 'form constant' hallucination [66]. In this work, the user's brainwaves are used as an input for adaptive sound and visuals. Another rather novel use of EEG data was presented by Venkatesh et al, in which the EEG headset was used on a person with severe motor impairment [67]. They used to be a violinist, and the use of a bespoke SSVEP-based BCI allowed them to continue to create music despite their impairments.

HRV (heartrate variability) is another useful physiological tool which can be utilized in the context of musical expression. Many studies have sown connections between heartrate variability and music. One example is the work of Iwanaga et al, in which they observed perceived tension and relaxation in users listening to music by composer Erik Satie [68]. Their results showed that sedative music produced a state of high relaxation and low tension. Another similar study by Zhou et al indicated that significant relaxation can occur during music therapy settings. Studies such as these indicate verifiable proof that music can have a direct effect

on our physiology and allow listeners to experience bodily affect through these sonic works.

2.4.2 Liveness, or What Does it Mean to Perform Live?

One of the driving tenets of my work focuses on what it means to perform live, and on a more specific track, what it means for a work or expression itself to live. *Liveness* is a growing field of research which seeks to quantify and debate what exactly gives an expression or work of art life. One such research collective is *Neurolive*, a multidisciplinary group of artists and researchers who aim is "to examine a range of core elements that influence live experiences, acknowledging the multi-faceted and culturally-specific nature of liveness in different contexts" [69].

This perception of liveness and the things that can be attributed to conveying this sense of a living thing is a greatly debated and discussed topic. In his book *Liveness in Modern Music: Musicians, Technology, and the Perception of Performance*, author Paul Sanden posits that the perception of *liveness* does not rest solely on the actual live performance being viewed but rather on the perceived performance and "perceived encroachment of electronic technologies" [70]. Furthermore, he discusses how *corporeality*, or the lack of this perceived physical body, can be utilized two-fold: on on hand, the sense of physical form can enhance the perception of *liveness*, while the intentional lack of this physical body can in fact strengthen the perception or interpretation of a works *liveness* [70]. One issue that plagues a large swath of modern day performers and composers relates to the use of electronics and laptops in live performance. Contrary to traditional instrumental performances in which a recognizable instrument is being played, laptop and electronic music often times does not have this. Instead, an extremely versatile instrument is being played, one which virtually any sound can be produced. In the work of Bown et. al, a study of perceived liveness in live laptop music suggests that perceived *liveness* can exist "as a manifestation of performer control beyond the paradigm of instruments being manipulated by traditional physical gestures" [71]. In this context, it is not specifically the performer manipulating or controlling a recognizable object with recognizable motions but the intervention of the artist that contributes to this overall perceived *liveness*.

The specific spaces in which performances occurs has some kind of impact on the perceived sense of *liveness*. Much of the perception of a live event is rooted in the communal act of experiencing a work within a given space and group of people [72]. The role that the audience plays on this perception of liveness can hinge on the dynamic between how one relates to the material and how they exist within an often times anonymous crowd [73]. The perceived liveness of a work is not necessarily rooted in the interactive nature or real-time functionality of a work, whether it is a performance or an installation. On the contrary, it is the real-time responses which present a claim to liveness that the audience must accept [74]. Therefore, the *liveness* of a work lies as much in the perception of the audience as it does in the people responsible for creating the works. *liveness* is more of a dialogue than a binary or one-directional expression.

2.4.3 Avatar Performers

Portraying the presence of a person, or really any living thing, is a central theme of my research. Through the use of sound and affect, my work aims to represent a living person (i.e. the performer or composer) through several different manners. One of the more prominent ways this has been achieved in recent times is through the use of avatars. In 2007, Crypton Future Media released their Vocaloid voice-bank for the character Hatsune Miku. Depicted as a 16 year old girl with aqua-green pigtails, her voice was generated through a series of vocal samples which are utilized in the Vocaloid software which enables users to program the lyrics and notes. Providing these tools allows the user to use this avatar as a means for expressing their own musical thoughts and intentions. In addition to her vocal software, her appearance has been used in countless live performances in which she is projected onto a scrim and is backed by a live band. Providing the visual representation along with the musical sounds further emphasizes the presence of this avatar-mediated communication. Despite her live performances not involving a human performing as her, the distinction seems to not matter to her audience. This virtual representation can act as an agent for perceiving or interpreting the specific emotions or intentions of the creator behind the screen so to speak [75]. The audiences can feel a direct and live connection to her performances, which begs the question: what does it mean to perform live?

Another prime example of avatars being used in live performance is with Damon Albarn's avatar group Gorillaz. Formed in 1998 by Albarn and artist Jamie Hewlett, this group utilized animated personas as the visual representation of their group. The lines between what is reality and what is a fictional representation are at times blurred, creating a live performance experience in which the virtual and the real are coalesced into something new. Roberta Hofer describes the live experience of Gorillaz as "a colourful bouquet of different stages along the spectrum of fiction and reality" [76], in which the audience is aware of the live performers yet they are able to accept these holographic animated characters as existing within some kind of altered or make-believe reality. The virtual and the physical are part of the same expression.

With much of the current practice of utilizing avatars or external agents as expressive elements of live performance, my work will shift this focus onto how the perceived *liveness* or presence of the performers can become the agent without necessitating a human connection to it on the part of the audience. Instead, my work will use this presence indicator as another performer of sorts which can serve twofold: as a reflection of the current state of being of the performer(s) and as a unique sound object which can contribute equally to the overall sonic palette.

2.5. Position of My Work

The work that I am presenting is deeply rooted in the inspiration and influence that these related works and many others have had. It is not intended to be presented as something that is fixing any problems within these works, or to invalidate the works which have led to my methodology. Rather, my method is a result of the guidance and inspiration which these works have had. In that sense, my work should rest easily within the existing canon of sonic works which seek to explore new performative dialogues through the use of novel technological interventions and a philosophical study into the affect, intention, and possibilities of new performance practices. Much in the way that the early influences of Kate Bush and Karlheinz Stockhausen have had on the works of Bjork, my work takes influence from her work and attempts to use this inspiration to guide the method which I have developed.

Throughout the development of my work, I have come across several ways in which my method can enhance and provide new avenues of expression within this existing canon. Firstly, the ways in which robotic artifacts have been utilized have been a large inspiration in my work. Much of these works are utilized by a direct control and intervention by the performing artist, as seen in Bjork's *Biophilia* and the work of Chico MacMurtrie. With my method, I present it as a way to utilize these robots in a way which is passively connected to the existence and presence of performers and composers, thereby offering a direct yet substantially live method of interaction and performance. Another area in which these related works have inspired my method to strive for unique areas of expression is that of the use of recorded media as an expressive tool. While the artists associated with musique concrète sought to capture the sounds of the world around them as compositional elements, my method suggests to use these mediums as a way of portraying musical intention in a way in which the medium itself becomes a way of coloring time. A quote which stands strong in my mind is from Cedric Bixler-Zavala. In his interview with Zane Lowe, he mentioned that "music is the best way to decorate time" [77]. This quote really resonated with me in the sense that it speaks on not just the power of sound and music to portray emotions and intentions, but how these expressions can be affected by time itself.

2.6. Definitions

In order to provide a clear guide for the following thesis discussion, I am including some general terms and definitions which will occur throughout. These will cover the topics of Musical and Physiological terminologies.

2.6.1 Musical Terminology

1. **Timbre**: the quality of sound perception for a musical note, sound, or tone.
2. **Harmony**: simultaneously occurring frequencies, pitches, or chords.
3. **Consonance**: Relationship between pitches or events that appear ordered or pleasing.

4. **Dissonance**: Relationship between pitches or events that appear disordered or not pleasing.

5. **Counterpoint**: The combination of two or more distinct melodies into a unified harmonic texture, preserving the unique linear characteristics of each.

6. **Cantus Firmus**: Pre-existent melody underlying a polyphonic musical composition [78].

7. **Texture**: The manner in which tempo, melodic elements, and harmonic components are interwoven within a musical composition, influencing the overall sonic character of the piece..

8. **Extended Techniques**: Innovative, unconventional, or non-traditional approaches to vocalizing or playing musical instruments, utilized to produce unique or distinctive sounds and timbres..

9. **Temperament**: a system in which musical sounds are divided and tuned. This includes the ratios in which the musical scales are divided, and the relationship between successive notes within a given system.

2.6.2 Physiological/Technological Terminology

1. **EDA (Electrodermal Activity)**: of or relating to electrical activity in or electrical properties of the skin.

2. **HRV (Heartrate Variability)**: the physiological phenomenon of variation in the time interval between heartbeats.

3. **P-Value**: how likely any observable difference between groups is due to chance.

4. **OSC (Open Sound Protocol)**: A protocol for interconnecting sound synthesizers, computers, and various multimedia devices, typically for applications like musical performances or show control..

5. **Max/MSP**: a visual-based programming language developed by Miller Puckette, which serves as the core software development tool for my works.

Chapter 3
Sonic Vessels Concept

3.1. Vision

What I envision for *Sonic Vessels* is to create a new form of dialogue and context for performative works. More specifically, to develop a framework through which artists can convey their presence in new performative dialogues between performers and their own physiological data, mirroring the performance practices rooted in communication between two or more performers. This concept can also be easily applied to remote, unattended, or even virtual exhibits.

To further define my concept of *Sonic Vessels*, it can be simply broken down as follows:

1. *Sonic*: denoting, relating to, or of the nature of sound or sound waves.
2. *Vessel(s)*: a hollow container.

The reason I chose sonic as a leading term is quite straightforward. I am working primarily with sound and using sound as the primary means for eliciting emotions from the audience and conveying the intentions and lives of the performers. For vessels, I intend on using various objects to convey and portray these intentions via sound. For instance, whether it is a koto, a speaker system, a handmade object, or even an empty space, these "vessels" will carry the presence of the performers involved in these works.

3.1.1 Externalized Performer Presence

Representing or externalizing the presence and liveness of the performer and/or composer is a crucial element of this method. By representing the passive presence of a performer, we allow them to communicate with and respond to their own

presence. With passive presence, or the passive physiology of the performer, there is a degree of separation from the intention of these gestures or signals. Utilizing these unintentional signals allows for the performance to exist as a novel dialogue between when a performer can control and what they cannot. In his book "The Language of New Media", Lev Manovich states that "human intentionality can be removed from the creative process, at least in part" [79]. This removal of intentionality is not absolute, but rather gives a certain independence to the externalization of the performer, thereby making a stronger sense of communication between a performer and the personification/sonification of their presence.

Furthermore, this kind of performance scenario can give a glimpse into how performers view themselves and their presence on a stage or performing environment. Often times, as a performer I find myself incredibly uncomfortable with my own presence on the stage. Since I was quite young and just starting to perform live, I generally find myself much more comfortable being in the background of a performance. If I must be on stage, it is better if I am not the main visual focus of the performance. This in and of itself is not a core element of the *Sonic Vessels* method but it is tangentially related to a core element: how a performer's presence can be viewed of experienced outside of the normal view. By utilizing an external means of sonification-based representation, such as a bespoke robotic musical instruments, analog synthesizers, or even a non-visible musical voice, the presence and existence of a performer can take on this perceptive element of a live performance. This not only affords the ability to remove parts of oneself and place them into something outside of their own body, but it also brings up an interesting angle to live performative dialogue: how does a performer respond to an externalized version of themselves, and how will this shape a new performative direction?

Although not all performances are the same and speaking of what constitutes a "traditional" performance can bring up a number of philosophical and aesthetic issues, in general there are certain characteristics of a live performance which are common. In Table 3.1, you will see a rough comparison of so-called "standard" performances and *Sonic Vessels* performances. Again, I will reiterate that this is not an all-encompassing guide. It is merely meant to show that this method I have developed can allow for novel approaches to performance when compared to

most standard performance setups.

Table 3.1 Comparison of Standard Performances vs *Sonic Vessels*.

Standard Performance	*Sonic Vessels*
Real-Time	Real-Time and/or Non-Linear
Responsive (Active)	Responsive (Passive + Active)
Performers Are Present	Performers are Present and/or Represented

3.1.2 Conceptual Research Structure

The main structure of my research concept consists of two modules:

1. Externalized Performer Presence
2. New Compositional Methods

Externalizing the presence of the performer is achieved through a multi-modal approach which involves a combination of physiological sensing, passive engagement, and musical interactions from the performers. This form of presence acquisition and implementation then inherently produces new compositional and performative methods. In this sense, the two modules are neither independent nor inseparable from each other. Instead, these two modules act as two parts of a whole, much like a binary form found in musical works. While the two sections have distinct differences, they are still closely related in other ways and combine to present a cohesive unified expression.

These two modules will break down the concept into smaller sections to clearly state the overall structure of the *Sonic Vessels* methodology and clearly explore each individual stage and component as they are introduced. Gradually, these elements begin to combine and formulate my final presented method, much like the development and research process involved.

3.2. Module I: Externalized Performer Presence

The use of physiological data in music has been used in a number of ways. One such way is the use of physiological data as a method for curating music playlists

based on the listener's physiological data. Deger Ayata et al utilized GSR and PPG data to develop a physiology-based music recommendation system for use in music streaming services [80]. On a more observational level, Javier Jaimovich et al utilized heartrate and EDA to observe emotional responses to musical excerpts [81]. In a more directly musical application, Elaine Chew et al state that "the strong similarities between the human pulse and music means that heart data can be readily mapped to music" [82].

This kind of creative and expressive use of the human physiological signals is a core expressive tenet of my *sonic vessels* concept. If we can detect and utilize certain physiological data trends which are connected to things such as engagement level, relaxation level, and excitement level, these can then be applied in a compositional and aesthetic manner. To achieve this kind of connection between the physiological and the performative, these numbers can be utilized within parameters in software such as Max/MSP, which is the primary software platform I am using in my work. So far, I have found some success in mapping these data streams to gestures such as triggers, amplitude levels, and gestural selection. As seen in Fig.3.1, this kind of mapping of physiological data to musical elements or structures is in many ways a choice which is left to the artist. With that said, this figure illustrates a principle mapping which has been used in several of my recent works. This was determined mostly based on how I receive this real-time data. Average BPM remains the most similar to audio or cv triggers, while HRV offers a more fluid stream of data. These general characteristics led me to determine this particular mapping, although artists could of course freely experiment with this.

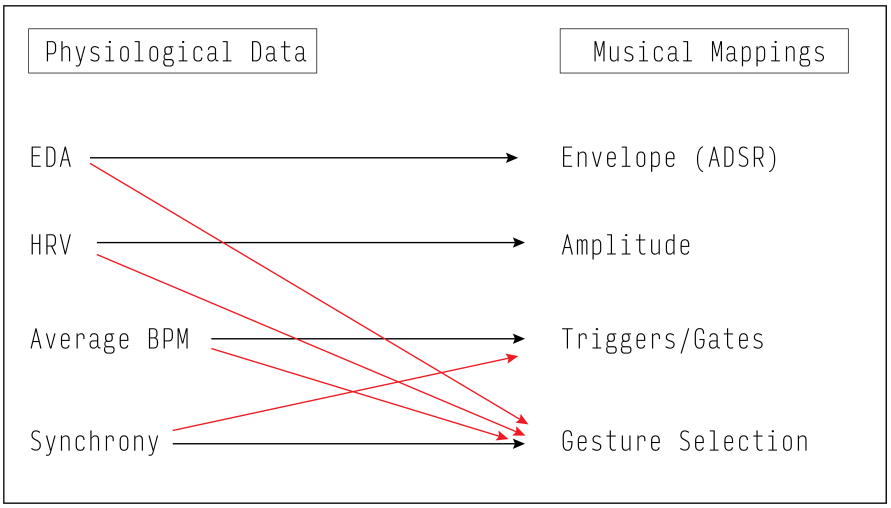

Figure 3.1 Sketch of Incoming Data to Musical Mappings (Red lines indicate more than one musical mapping).

Biodata	Gesture	Visual Mapping/Score Indication
EDA	Structure	
HRV	Tonal Center	
PNN50	Harmonic Strength	
Average BPM	Textural Density	
Synchrony	Rhythmic Synchrony	

Figure 3.2 Macro Level Compositional Responses

To further investigate the many ways in which this data can be used, more focus is placed on macro level compositional implementation such as overall structural decisions, harmony and tonality, and degrees of rhythmic and textural content. In Fig. 3.2, you will see five kinds of presence indications, the corresponding macro level gestures which they are tied to, and a visual sketch of how these biodata

streams play out over time. While this is a preliminary sketch of how these elements occur in a composition, every one of my presented projects employs some form of this kind of visual representation and visual score.

3.2.1 Musical Structures and Physiological Data

In music, there are varying opinions on what exactly the core elements are. According to Howard Owen in *Music Theory Resource Book*, these elements are pitch, timbre, intensity, and duration [83]. Another opinion is that the main elements are pitch, duration, loudness, timbre, sonic texture and spatial location [84]. For the sake of clarity, I will focus on the latter of these. Including spatial location as a foundational element of sound art is crucial. If we take these six elements as the foundational aspects of any sound work, we can begin to build a more structured and specific approach to the implementation of physiological data. For instance, Fig.3.3 is an excerpt from the visual diagram of the foundational elements of the sonic performative work *Spectral Counterpoint*, which will be further discussed in Chapter 5. In this diagram, the involved people of this work are shown as existing in Los Angeles, Hiyoshi, London, and anywhere (for the performer). In this case, I was the performer and was located in Odaiba, Japan. All outbound data is shown in red, all outbound music is shown in blue, and the performative control is shown in green. As you can see, data is flowing from all remote locations, all music is outbound from the performer's location, and all performative control is relegated to the performer.

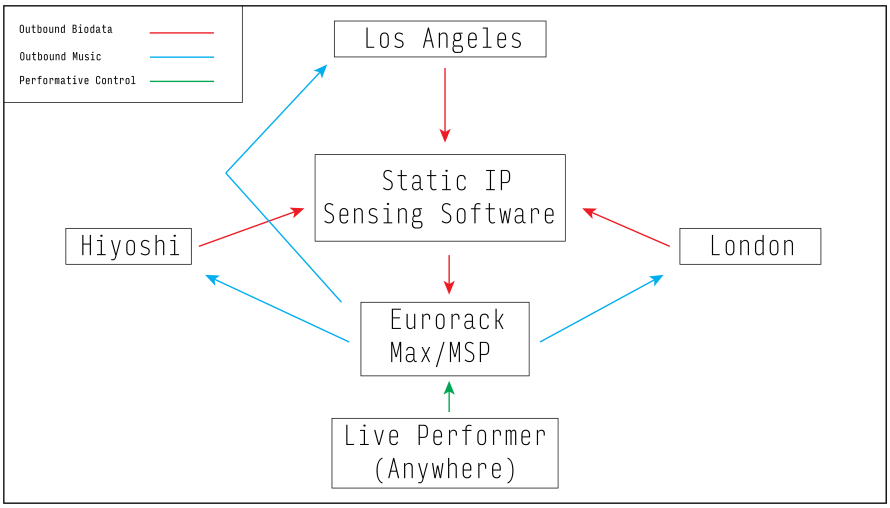

Figure 3.3 Diagram of the Flow of Communication in *Spectral Counterpoint*

When these parameters are reliant and adaptive to the real-time data of the performers, the audience, or both, the resulting experience will be one that is specific to the people involved in it's creation. Instead of a performance existing as a live experience only once, the "liveness" of the performance can exist outside of the conventional bounds of the performance.

This approach lends itself to a number of implementations and creative approaches which can exist in isolation or in combination, such as:

1. Performance structures which utilize physiological data as a guide for the structure of a work.

2. Pitch and duration specification based on physiological data and/or synchronous events.

3. The pitch-class, temperament, or intonation of the performative work.

4. The tempo of a performative work.

While this is not an exhaustive list, these are just a few examples of implementations which will be discussed in this thesis.

One example of a combination of sensing data implementation was utilized in the work *Innermost Echoes*, which I will discuss in more detail in Chapter 4. With

this work, we used the heartrate, HRV (heartrate variability), and EDA (electrodermal activity) of 2-3 performers as the control data for macro-level structures within the live work itself. More specifically, the instances of synchrony between the two performers acted as a trigger for sharp increases in loudness of the robot koto and timbre of the Eurorack synthesizer, while the individual average heartrate and EDA of each performer determined the pitch class and plucking rhythms of both instruments. While this was only a preliminary experiment, it proved to be a solid starting point for further investigation.

The initial inspiration for using physiological data as a compositional element came from my early work at Keio Media Design, which will be discussed in greater detail at the end of this chapter. In essence, it is the seemingly indeterminate or at times unpredictable nature of our physiology which inspires me to use this as a method. Although there are certain aspects which we can anticipate in regards to the typical responses our physiology will produce within certain situations, it is this fluctuation and at times unexpected result which I believe can lead to new performative results, and in turn produce unexpected or unusual compositional expressions.

3.2.2 Physiology and Musical Gestures

When dealing with any new kinds of technologies or techniques in the creation of music, it is imperative that the composition process itself take these changes into account. With the introduction of electronic interfaces in contemporary music composition, creators in many ways found themselves with a new approach in which the exploration of the technology and sound sources would inform the composition process [79]. This can also lead to an approach in which "tools must strongly affect the essential parameters of sound in order to create a 'distorted' perception of them" [85]. According to STEIM Emeritus Director Joel Ryan, "these streams of data generated from the performers and the composers can allow for any number of applications within these musical frameworks, and gestures can be expanded or elaborated at any level of interpretation from the sensor data, to 'note events', to the samples of sound" [86]. By using technologies to rework existing sounds and gestures, the reformative approach to working with sound should inherently adapt the composition process to embrace this.

Upon the advent and integration of digital approaches to new media works, a shift in the perception of these expressions and the dynamic between process and culture came to pass. When the medium itself changes, a simultaneous change in approach is inherently going to happen. The materiality of analog mediums versus the digital nature of code and newer technologies poses an interesting dynamic, yet when physiology is an integral part of this relationship, it creates a stronger connection to these mediums. It has been argued that artworks which are created in software are inherently numerical representations [87]. While I do not disagree with this sentiment completely, I do believe that a mixture of software and hardware/analog mediums extends or expands this representation into a more closely human affect.

When taking into account the mediums through which these stories of expressions are presented, the process of transcoding will undoubtedly occur. This process of mediums defining the artistic output through which they are being used can be broken down into a "cultural layer" and "computer layer" [88]. These two layers are not fully independent from each other, but in fact influence each other significantly. The very nature of a film stock will have an impact on the resulting images or sounds, which will in turn influence the content which is being displayed or recorded onto them. Much like a composer must take into account not only the acoustic properties or physicality of each instrument in the ensemble but also the place in which a performance will be held, new media artists must take into account the properties and nuances of the mediums they are utilizing. Without this care and consideration for the nature of the mediums, the resulting works could take on unintended aspects or, worse yet, fail to express what the artist hopes to present.

The use of physiological sensing applications in the context of *Sonic Vessels* facilitates a new approach to formulating the works themselves. This is done by detecting varying forms of physiological data and then applying them to the main elements of the musical works. As seen in Fig. 3.4, this is a preliminary diagram of how each separate element of the music can adapt based on data received by the performers and the audience.

By applying these physiological signals to the building blocks of the work itself, it can become a group effort in the realization of the performance itself. So much

of what we engage in with live performances is rooted in the connections and dialogues between each other. These networks of communication comprise the web of dialogue that constitutes the overall group expression. When these individual expressions are dependent upon or at least inspired by the passive physiology of the other performers (and of course the passive physiology of oneself), a new thread of communication is achieved which strikes much more directly into the being or liveness of the performers in that moment. Placing this liveness on the very building blocks of the performed works, these works can live and breathe as constantly changing and personalized experiences.

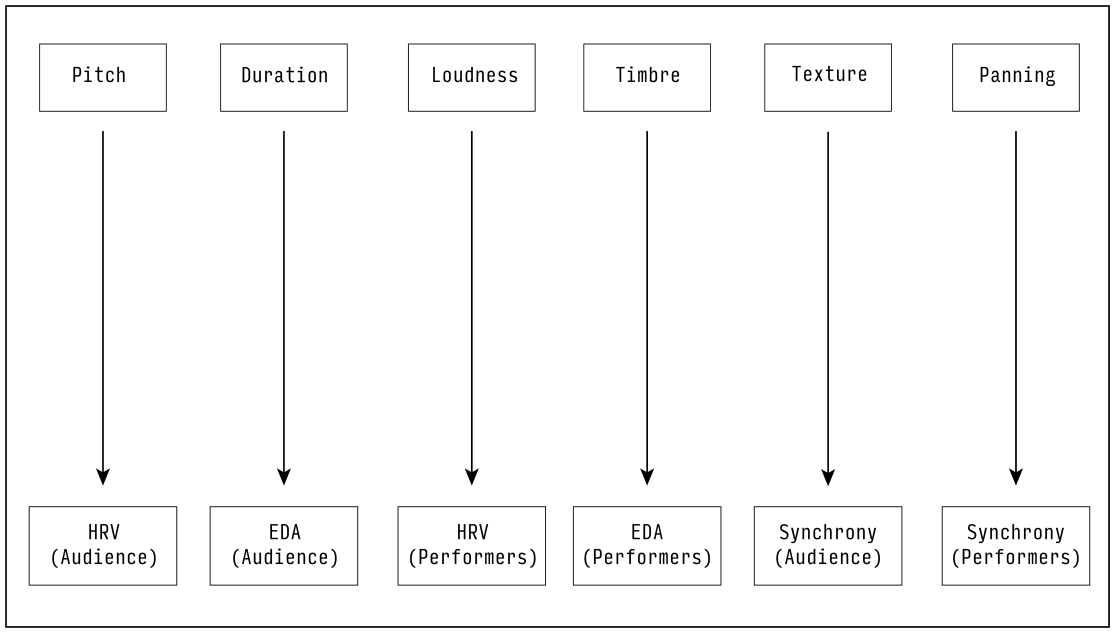

Figure 3.4 An example of physiological data applied to each aspect of the musical work

I have been keenly aware of these necessary compositional changes and have made it a priority in observing these ever-changing dynamics throughout my work thus far. One of the most prominent adaptations of the compositional approach is the relationship between a live performer and their own live physiological data. This was first explored in the *Boiling Mind* project which will be discussed in the next section. By seeing how a dancer's data comes in while they are performing

such a physical expression, a deeper understanding of how the adaptive sonic landscape can support and communicate them is achieved. In the past several months, changes in the larger compositional structures of my works that involve live data have been discovered. One of the biggest changes has been in the regularity of the large-form harmonic rhythm (the duration and frequency of changes in harmonic content). The harmonic structure of music is one of the most basic and important elements of music, and one that can be easily experienced and detected by audiences. Within harmonic structures, there are hierarchical structures of stability depending on the context in which these harmonic elements exist [89]. Much of these hierarchies relate to perceived consonance or dissonance. When a harmonic progression presents what is known as a leading tone, this is typically something which is discouraged to double [90]. These leading tones have a tendency to lead to a resolution, such as the tonic. This perceived tendency creates a hierarchy wherein these leading tones present a strengthening for the resolution such as the tonic. While it goes without saying that these rules are not and should not be militantly observed as an absolute truth, these tendencies are ingrained within much of the music we consume. When these expectations and hierarchies are dependent on physiological data, this new kind of structural composition will need to be addressed and taken into account from the initial inception of the creative process. Connecting this to the presence of the performer could lead to rather stunning and evocative forms of expression. A prime example of this was discovered in the preliminary groundwork for developing the Max/MSP patcher which was used throughout most of my work. In the early tests, live biodata was used to determine the harmonic and melodic movement of four oscillators, all structured to work within a central key of G minor. When allowing these oscillators to move around freely, each based on a different stream of biodata, the results were mixed. On one hand, some unusual voice leading created some tension and lack of resolutions which gave the overall perception of the soundscape a feeling of having no strong harmonic resolution. On the other hand, there were some unexpected clashes between voices which presented a dissonance which most likely would not have been discovered were it not for the biodata. Having many years of formal training in music theory and counterpoint, I find myself at times almost restricted by this knowledge. Of course, compositional choices allow for the

manipulation and omission of following these common theoretical musical rules, but some unusual or unexpected harmonic and melodic gestures may at times be omitted simply because they "don't work" or don't follow standard practice. It is because of these omissions on my part that the use of live biodata and liveness in performers has become such a central part to my work. It has afforded me the ability to look past my own self-imposed restrictions and explore new tonalities and contrapuntal relationships in which I do not have absolute control, but instead act as a shepard in guiding these organic and flexible streams to new sonic expression. These early explorations will be discussed further in 3.3.2.

3.2.3 Reflective Sound and Agency

One important distinction I need to make is how this method utilizes sound as a reflection of the user (the user meaning the performer, composer, audience, object, etc). In the words of composer Beatriz Ferreyra in "Perceive, Feel, Hear..." from *Spectres: Composing Listening*, "the sound and it's relation to another sound becomes a tool in the service of meaning, used to express, depending on the inspiration of the moment, an intuition of something fundamental" [91]. This passage has stuck with me for some time now. The way different sounds interact with each other is much like our interpersonal connections. The way each responds to and co-exists with one another has a massive impact on the perception of the individual entities. When multiple voices are ringing out, they become much like a collage in which many discreet objects are reverberating against one another, creating the perceived whole. The same can be said for social interactions, wherein a group of people are collectively sharing their existence and emotions.

Attempting to reflect the emotions of the user is where my initial exploration began. I wanted to reflect the emotions of the user in the installation work *Sonitecture: Module 1.1*, where these sea-like creatures would reflect back the emotions of the people surrounding them and, in a sense, act as a mirror of sorts. While I found a great deal of inspiration in this approach, I quickly found it nearly impossible and even rudely presumptive of myself to insist that I could actually know the emotions of the user. With the kinds of physiological sensing technologies this method is deploying, we are able to detect levels of *arousal* and *relaxation*, which are in and of themselves a bit vague. One person's arousal could be tied

to fear while another's could be tied to joy. The same is true for relaxation. To suggest that we are detecting somebody's internal emotions simply based on these arousal/relaxation levels involves far too much presumption on our part. Therefore, the relaxation and arousal levels are used as a presence indicator without the implication of emotion itself. Emotional responses to the music can and should stay within the interpretation of the user.

Drummer and composer Chris Corsano described the concept of *resonant improvising* as a "group 'ringing' itself to create an intentional feedback system" [92]. He goes on to describe how these ringing events or gestures can be accomplished through musical elements, but also "on more abstract levels by reaching a shared emotion/feel/touch/etc.-whatever makes some of the separate selves in the band melt into each other a bit" [92]. These more abstract interactions are crucial to achieving a shared performative dialogue between performers, and even more imperative when including abstracted objects such as robotic instruments or software which is sonifying the presence of other performers. Despite these sonification objects not being living beings themselves, they act as *vessels* for the presence of the performer. They are beholden to the feelings and liveness of the shepards of their input stream. As performers interacting with and responding to these objects, it is important to respond as naturally as possible and allow for these objects to melt into the collective whole of the ensemble, thereby eliminating the distinction or segregation of the objects as separate from the performers themselves.

When we think about the agency of the performer in live works, there are several issues that arise. One such issue is that of the relationship between the performer and the object/medium through which they are conveying their intentions, ideas, and (arguably) their emotions. The instrument through which they are conveying these intentions can be seen as something which is separate from and at odds with the performer [93]. In other words, this object is not a living thing; it is comprised of various physical materials assembled to produce certain sounds, or in the case of electronic music, a mixture of hardware and software code, or even simply analog circuits. This in and of itself will produce no sound. It is through the intervention of the performer which produces these sounds. But what happens when we attempt to give some sense of agency or "awareness" (not in a literal sense) to the performing objects? Does this reduce the agency of the performer?

Does this split the difference?

Within *Sonic Vessels*, this question of reduced agency is explored through the use of bespoke musical objects which are directly tied to the performer and/or audience, and by the process of composing music in which certain decisions are taken out of the hands of the composer via physiological sensing data implemented in real-time. When these decisions are moved from the control of the performer/composer and placed within the control of things which cannot be actively controlled, a greater sense of unique outcomes will occur. In his book *A Year With Swollen Appendices: Brian Eno's Diary*, the composer/producer/visual artist describes that "an experimental composition aims to set in motion a system or organism that will generate unique (that is, not necessarily repeatable) outputs, but at the same time, seeks to limit the range of these outputs" [94]. Structuring this work within the context and control of parameters which cannot be controlled thereby allows this process to play out as Eno states. These structures can be anticipated but not wholly known until the performance takes place. The output which this system/organism presents will inherently be as unique as the bodies which are producing the input, yet will be limited within the compositional framework. There is a stress on the emphasis of furthering the dialogue between the specific roles in live music making, including composer, performer, instrument, and audience. While there is not a specific pre-described solution or framework to all live performances, there do exist certain roles, even within a performing group, that can be seen as common or expected.

In the performance work *Spectral Counterpoint* which will be discussed extensively in Chapter 5, this reduced agency was extensively explored as a core part of the concept. In this work, the incoming data, or liveness, from audiences in different remote locations is placed in a commanding position in terms of the harmonic movement, tonal selection, and gestural intensity. As the main performer in this work, my position within the performative hierarchy felt much more like a collaborative position when compared to more traditional settings. My role became more like that of a conductor or live mixer, where the liveness of remote listening participants presented their presence as a control mechanism through which I would act as a guide for these incoming streams of data. Although the audiences/remote participants were many kilometers away and could not be visibly

seen, their liveness was very much present in the work. This inherently reduced the feeling of free agency from my own perspective. This was not a performance situation in which I had free control over determining the gestures, sounds, and harmonies. Instead, I was limited to intervening in these streams of liveness and experimenting with how these streams were applied to different musical artifacts. The role of mixer or, as I described it at times, a shepard of sound, is something which I have only found within this particular performance dynamic. This new role of "sonic Shepard" has come about from the development and application of the *Sonic Vessels* method as was explored extensively within much of my current work, and will continue to be explored in future performances such as *Sonic Resonance* and others.

3.2.4 Recorded Media, Memory, and Affect of Fidelity

Numerous forms of recorded media has existed for centuries. Some of the earliest forms of recording mediums were in the form of early musical notation, which date back to the 9th century [95]. Several hundred years later, the earliest form of audio recording took place with the invention of the phonautograph, which was used to record the oldest known audio of the human voice [96]. This would pave the way for audio recording techniques and scientific pursuits in audio technology and science.

Recording visual media also has it's roots in very early mediums which would eventually lead to technological means for documenting and reproduction. Techniques such as camera obscura, shadowgraphy, and magic lanterns have their roots as far back as prehistoric times. Photographic techniques saw a similar development in the 19th century, with the first photo-etching occurring in 1822 by French inventor Nicéphore Niépce, with the first photographic film roll being introduced in 1885. By the 1930s, photographic film had become much more widely used, and moving film had already become much more widely used.

In the 1940s, these mediums began to take on much more flexible and artistic representations, as editing techniques came to prominence. This intervention into these mediums would open up them to not only be used as a purely utilitarian means, but as a tool through which artists could express themselves much like painters or musicians had been prior. In the 1940s and 1950s, the rise of *musique*

concrète gave rise to the use of recorded media as an expressive tool in and of itself. As opposed to using the recording mediums as a tool for capturing images or sounds, the mediums themselves began to take on a much more important expressive role in the works. The fragile nature of magnetic tape would come to establish an aesthetic and identity all its own. This aesthetic relationship would only increase over time as these mediums become older and more seemingly nostalgic.

Figure 3.5 *Two Self-Portraits.* Left-hand picture taken with late 19th century tintype camera, 2019. Right-hand picture taken with medium format film camera, 2021.

As you can see in Figure 3.5, there are two self-portraits. The first one was shot on a late 19th century large format tintype camera which was restored by my father Steve. The second image on the right is another self-portrait which I shot on medium format color film using a Yashica B camera. Although these pictures were taken in 2019 and 2021, the overall appearance and feeling which one would glean from viewing them are quite different. The left image recalls a bygone time many decades removed from our current day. The right image, on the other hand, presents a more current-day feeling, with rich colors and a much more clear focus.

Although both of these portraits were shot on what some would consider obsolete or anachronistic mediums, the right image appears much closer to what we

would consider modern times. This poses an interesting question: when does the medium dictate the affect of a recorded gesture or image? Recent years has seen a rise in appreciation and interest in analog mediums such as vinyl, analog tape, and cassette tapes. Numerous artists have utilized older analog mediums as a crucial part of their sonic aesthetic, such as composer/musicians William Basinski, Blankfor.ms, Northern Tapes, Polypores, Blakmoth, and Burial. A number of recording artists, such as Radiohead, The Smile, and Sigur Rós, still often record their records to analog tape. Filmmakers Paul Thomas Anderson and Christopher Nolan both shoot almost exclusively on film stock, providing a steady stream of worldwide films which utilize film stock. What is rather interesting with this approach is that, despite these films and albums happening on a massive budget and scale, this honoring of analog recording mediums is still a big part of their approach. Despite the advances of digital recording technology, they still hold analog film in a high regard.

That is not to say that these artists eschew advances in digital technologies. Instead, there is a certain connection to these long-standing mediums which contributes something special to their work. It is not out of the question to expect some Max/MSP-produced sounds being committed to analog tape, which would then be edited and mastered digitally. This is where one of the most interesting aspects of this affection and utilization of older mediums comes into play: by combining these older and newer technologies and allowing them to co-exist and reflect off of each other, you end up with a sort of out-of-time palette to work with. It is neither current nor ancient, but an amalgamation of old and new methods.

In the work I present, there is a strong sense of analog integration alongside newer technologies such as data processing in Max/MSP and real-time physiological sensing. This, combined with analog mediums such as 1/4" tape, cassette tapes, and VHS, combines to form a past and present expressive palette to work within. This is not only a reflection of my interest in both analog and digital expressions, but on the affect that these approaches inherently have. Another strong reason for using older technologies is the fragile and often unpredictable nature they offer. Whereas a digital program should reliably function barring any unforeseen issues such as PC lag or a computer crash, analog mediums offer what I would describe as a pleasantly finicky nature. Since many of these machines I

use are decades old, there is no telling when one might stop functioning properly. The mediums themselves are also prone to age, with each use of a tape reducing its lifespan ever so slightly. This non-permanence provides an inspiring format to work within, knowing that with each use, its lifespan is that much closer to becoming unusable. Since a core tenet of my methodology is the liveness of these works and the people involved with them, it makes perfect sense to me to have the tools which I use to also have their own life.

As living organic beings, we are inseparably connected to time and decay. Our bodies and minds slowly decay along with the linear time we are given. In the words of filmmaker Guillermo del Toro, "everybody on this planet boarded a train that was final destination death" [97]. This kind of acknowledgement and acceptance of the temporality of life has been discussed, analyzed, and debated throughout history. My work does not mean to take a hardened stance on this, except to say that this is simply a part of the life we have. Life cannot exist without death. The present cannot exist without the past. Sound cannot exist without silence. The use of fragile technologies and recording mediums is reflected directly in the liveness of the work, in that these sonic artifacts share the same temporality that we as humans are unalterably given in life. In a sense, *liveness* is shown through the inevitable eventuality of, for lack of a better term, the *deathness* of it all.

3.3. Module II: New Compositional Methods

With the implementation and exploitation of this kind of presence-based physiological sensing data and multi-modal sonic performance, much has to be changed in the compositional methods being used. This module comprises the bulk of my *Sonic Vessels* method as it pertains to composers. It covers issues pertaining to hierarchies, performance structures and dynamics, traditional practices and their new role within these works, custom-built sound generators, and the new roles which are present in such a musical method. In many ways, it is the culmination of the methodology, a means with which we can realize this approach, and a macro-level structure.

3.3.1 Hierarchies in Live Performances

Hierarchies tend to exist in virtually all forms of creative musical expression. Whether this is a jazz ensemble, an orchestra, a rock band, or anything in-between, each member and contributor to this work will find themselves in a certain role and level of contribution. While these hierarchies can have varying levels of strictness or clarity, it is something that is still present nevertheless. Sometimes this role is something that will find itself in a state of flux and evolution even within a given project, as was studied by Aslan et.al. [98]. The role of composer versus composer/performer is one that is particularly of interest to me as I have found myself in this position for over two decades now. Although my thoughts on this kind of role were quite minimal in the beginning, I found myself struggling greatly with it during my time at Columbia College Chicago. It was here that I first began to compose music for other musicians to realize. Instead of my previous experiences of creating works which would be performed and/or recorded by myself and other musicians, my time as a composition student found me outside of the performer role. I was required to place all of my intentions for these works onto paper so that other musicians would perform it. This proved to be a very difficult task for me and I quickly found myself questioning my original ideas when they could not be properly described in notation (this being a lack in understanding on my part). Throughout the following four years of my studies, I gradually came to understand this highly complex relationship between composer and performer, and where we as composers, performers, and conductors exist within this ever-changing discipline.

In this thesis work, I find myself again coming to this issue of hierarchies and so-called "power dynamics" within sonic arts. Finding more specific roles and responsibilities in the people involved is not the focus of this exploration, but instead I prefer to acknowledge the shifting and flexible places that we can find ourselves within this method. There is no specific or correct place for each individual to see themselves. Rather, the perceived *liveness* aka presence of the people involved should take a stronger position in this dynamic, upon which the rest of us can comfortably position ourselves. Strict hierarchical roles are not necessary and in fact could deter from the very essence of this work. The roles and responsibilities of the involved parties can and should be flexible and undefined. It is important

to acknowledge that hierarchies do exist within live music works, but to allow these roles to become blurred and challenged gets to the core of this philosophy and method: a presence-reliant system for novel sonic works in which the passive presence becomes the active initiator of gesture and expression.

Let us look at these hierarchies from a macro view. In the grand scheme of musical performances, the hierarchical roles between the performers, the audience, and the objects through which these performances are expressed will change depending on a multitude of factors such as time, place, genre, and intention. But what about the hierarchy between a spontaneous performance and one that is heavily rehearsed, coordinated, and repeated? The exact hierarchical positions of these two methods do not have any strict importance but are more reliant on the intended outcome of the performers and the preferences of those who witness these occurrences live. What is interesting with this pseudo-dichotomy of spontaneous performance vs rehearsed/orchestrated performance is that the two can actually co-exist in some form. Free jazz improvisers are known to rehearse with each other in preparation for a performance, although the intended outcomes of these rehearsals may differ from that of a more rigid orchestral rehearsal. The intention is not necessarily to plan or determine what exactly what will happen, but instead to gain a familiarity with the expected performance setting [99]. While this kind of preparation could arguably be seen as providing a foundational structure akin to written notation, it focuses more on preparing a state of being in the performances, a familiarity with what could happen. Guitarist Derek Bailey states in *Improvisation: Its Nature and Practice in Music*, regarding free improvisation groups, "once the music hardens its identity to the point where it becomes susceptible to self-analysis, description and, of course, reproduction, everything changes." [100]. I interpret this statement not as a testament to one style or approach holding more significance than the other, but rather to suggest that with repeated spontaneous musical exchanges comes a reduced sense of risk or happenstance.

3.3.2 Reconciling Tradition in Non-Traditional Tonality

Contrapuntal Application

In his book *The Tradition of Western Music*, author Gerald Abraham states that the core of tradition "is perpetual life and change, very often slow and organic, yet often modified-sometimes quite violently modified-by external circumstances" [101]. This quote is extremely poignant in regards to my work. While tradition can have certain connective threads to one's upbringing and philosophies, they are indeed tied to the change and evolution that we as humans are bound to. Without allowing any change in our deeply held traditions, we reject any notion or possibility for discovering new connections to our surroundings or communities. This is especially prevalent in the sonic arts. In my early composition studies, I received some of the most poignant advice I have ever been given by my professor Marcos Balter. In one of my first workshop compositions for solo flute, I presented an admittedly sub-par sketch. In critiquing this workshop piece, he questioned why I was only sticking with standard notation and temperament. When I countered that this was what I was familiar with, he then forced me to base the entire composition on a tuning system outside of traditional 12-TET. While it was initially quite daunting, I am incredibly grateful for this advice and mentoring, as it helped to get me past the idea that what I knew and was comfortable with was enough to rely on. Especially within sonic arts, it is imperative to question why we as composers and performers would simply stick with a specific tradition or practice. While this is not to say that tradition or works based upon a certain tradition are inherently bad, it is also to say that this should not be the reasoning behind it either. Simply going blindly with a musical tradition for the sake of easy implementation or familiar expression will often create limits to how far these works can reach in terms of concept, performance, and affect.

With this new method of live performance practice which I am developing, I have made a concerted effort to ensure that traditional performance and compositional practices can exist fully and freely within the confines of the methodological framework which is being built. Although the sonic and performative aspects may differ, at times even greatly, the root core of tradition can still be ever-present. One such example is that of traditional counterpoint as it is expressed within

a presence-based sonic work. This was initially developed within an early work of mine titled *Sonitecture: Module 1.1.* This installation, which was first presented at Media Ambition Tokyo in April and May of 2021 at the Mori Museum in Roppongi, Japan, consisted of several deep sea inspired organisms which were hand-crafted using silicone and foam. They were placed within clear acrylic tanks decorated with seaweed and plant materials. Throughout the installation space were eight speakers which were installed within each of the three acrylic structures and on the rafters above the installation space. These speakers produced the sonic environment which was classified into three distinct groups:

1. Ambient background sounds of water flowing and birds chirping, slowed down by 300%.

2. Proximity-triggered sounds of a piece of wood striking concrete, processed extensively.

3. Tonal sounds produced within Max/MSP.

Of these three sound groups, the third (tonal sounds) was produced in a generative method using a fairly simple patcher built within Max/MSP. This patcher would select from a pre-determined set of possible pitches, envelopes, and dry/wet applications of a reverb effect, which were all based on how long and how close a participant was standing in relation to each of the three structures. Each of the three structures had their own specific set of sounds, which were all structured within a G minor tonal pitch set. With the first prototype, I felt as though it did not sound as though there was enough harmonic movement. Instead, it simply sounded like a constant G minor drone with slight variations within it. This is when I decided to apply some contrapuntal theory to the note selection and orchestration of sounds (how the sounds from each structure could interact with the others). To do this, I broke up the possible pitches and ranges of the installation as a whole (or an ensemble), and divided up these parts to the eight hanging speakers. This allowed me to assert a slightly more intentional control over the resulting soundscape, while still allowing it to breathe and flow in a more "traditional" contrapuntal sense.

Although the strict counterpoint found in the works of Palestrina or Gesualdo was not exactly shown through this early experiment, the core principle of treating

Figure 3.6 *Sonitecture: Module 1.1*

each voice in the ensemble as a singular melody which works hand-in-hand with every other voice helped to guide this work to a more cohesive and expressively-sound presentation.

Traditional Japanese Music

One of the earliest and still on-going approaches to traditional musical was through the project titled *Innermost Echoes*, which will be discussed in more detail in Chapter 4. With this project, a robotic koto is utilized as a means for sonifying the physiological data of the performers (typically a live koto player named Aoi Uyama, myself on Eurorack synthesizers, and more recently an erhu player named Juling Li). This came to be when I was able to purchase a full-sized koto for very

cheap. Myself and my main engineering collaborator George Chernyshov began working on fitting this koto with 13 solenoids and 13 linear actuators to give full control over the koto via MIDI protocol. Fortunately for us, a professional koto player (Aoi Uyama) joined our Embodied Media lab and immediately expressed interest in joining the project. Based on her extensive knowledge and skill at traditional Japanese music performance, we were able to integrate certain traditions within this project, including typical tonal structures and gestural patterns. Even though we have never set out to fully replicate the traditions present in Japanese traditional music, we made sure that we took these into account and honored them. This occurred after long conversations about what these musical traditions meant in a historical and political context, as well as how we could use this new performative approach to create our own unique voice within the context of what had come before.

Traditions in Japanese music stretch back to the early 8th century [102], although music in Japan most likely existed prior to this. Much of the early influences on Japanese musical traditions stemmed from isolated Chinese and Korean clans [102], and were often times strongly rooted in social and political classes, each with their own structures and voices [103]. Another strong element of traditional Japanese arts which has been a big influence on this work is the ways in which silence and natural sounds are understood and appreciated. The concept of silence, which is known as "ma" in Japanese, is a concept which is utilized greatly in traditional Japanese music and are deployed in a similar manner to auditory gestures [104]. Rather than viewing silence as the absence of sound, it can in fact be seen as an intentional and expressive omission. In the 9th century writing *Genji Monogatari*, there is extensive discussion on the beauty of the sounds of nature [105]. This appreciation of the very sounds of the world as musical is reflected in much of the musical traditions and is a strong component in my current work.

The decision to go with our own tuning system versus trying to replicate an existing traditional koto tuning came about due to the physical nature of the robotics which we built onto the instrument. Contrary to how a koto player typically performers the instrument by plucking with one hand and bending the strings with their other hand, our robot koto activates the strings from a series

Table 3.2 Comparison of two traditional Japanese koto tunings and the robotic koto tuning.

Hirajōshi	Kumoijōshi	Robot Koto
D4	D4	A3
G3	G3	B3
A3	Ab3	C4
Bb3	C4	F4
D4	D4	D4
Eb4	Eb4	B3
G4	G4	A4
A4	Ab4	E5
Bb4	C5	Ab3
D5	D5	B4
Eb5	Eb5	G4
G5	G5	D5
A5	A5	B4

of solenoids in a line while pulling the strings from below via linear actuators. Since our linear actuators are all calibrated to pull down at their maximum range to result in a consistent half step manner, our design necessitated the use of a secondary set of bridges and a more intermittent tuning system as opposed to the sequentially tuned koto. In Table 3.2, you will see a comparison between two traditional tuning systems (Hirajōshi & Kumoijōshi) and our robotic koto tuning system. This was determined after several iterations of alternate tuning systems, which eventually led to this standard tuning system we utilize. Although other tuning systems have been used with our robotic koto, this is the one which is most commonly used. More on this will be discussed in the following section.

3.3.3 Exploitation of Bespoke Musical Instruments

Acoustic Instruments

The use of custom-built bespoke instruments or sound devices has helped to elevate my *Sonic Vessels* work and give it one of its defining characteristics. This all

began with a rather accidental or happenstance occurrence. My frequent collaborator George Chernyshov and I had started discussing the possibility of building a robotic musical instruments around the end of summer 2020. We did not have any particular reason or idea for it beyond simply using it as an exploratory side-project. One of the first ideas (and one that we still very much intend on making at some point) was to take a taishōgoto, known also as a Nagoya harp, and make it destroy itself. On the surface, this sounds rather silly, but there remains something quite appealing and exciting about building something that would eventually destroy itself. The catharsis of watching this thing we spent so much time and energy on simply breaking itself into unusable pieces of scrap wood and metal could be in of itself a cathartic experience for us. However, the initial ideas we threw around never fully came to be realized as of yet. The one constant with our early ideas was that we wanted to exert robotic control over an acoustic instrument, much like many great composers, builders, and artist have done in the past. To take the direct control one or more steps away from the actual human body playing these instruments offers an appealing and fascinating approach. It offers up questions and issues regarding agency and control, authorship, and even questions who the instrument really is.

Fast forward to summer 2021 and a further idea came to be. After a somewhat frustrating time with a previous exhibit, we decided to take something that we had been perfecting over the past year and a half (physiological sensing) and apply it to our robotic musical instrument idea. At first, we of course still wanted the instrument to break itself. That idea had taken hold of things for quite a while. As we continued to brainstorm over how this could happen and what instrument we could use, we eventually decided that an upright piano would offer the most usable surface to work with and also provides an immense tonal range. The one big problem with this is the massive size of a piano. Where would be keep this piano and how would we move it around for any live performances or installations? Those big issues aside, we kept the idea in the back of our minds while working on other projects for a few months.

Fast forward again to October of 2021, and the idea somewhat landed in our laps. While traveling back to our Hiyoshi lab from Musashi-Koyama (about 30 minutes by train), I stopped by a local Hard-Off to check on some old cameras.

Hard-Off is a goldmine for used gear, and this location in particular is known for having a great selection of old cameras and occasionally old musical instruments. While looking through old cameras and parts, I saw what would eventually become a huge part of our lives: a full-sized koto for only ¥1000 (roughly $6 USD). Without hesitation, I bought the oddly affordable koto and carried it by hand all the way back to our lab. As I walked in, I announced that we had a koto, and after a few seconds of confusion, George replied "alright, we have a koto?". This is how our robotic koto came to pass. A random trip to Hard-Off offered us the path towards this extensive exploration of bespoke robotic musical instruments and how physiological data can be combined with it to create new performance dynamics and expressions.

Liveness and Performance with Recorded Media

The use of recording technologies has been present for many years. Some of the earliest forms of recording music came in the form of written scores which date back to 1400 BCE in Babylonia [106]. After written notation came devices which were able to record musical information, such as the music box [95] and later the player piano [107]. Finally, the first instance of audio recordings came with the phonograph [108], which was able to record sound onto a pre-grooved cylinder which was wrapped in tin foil. The quality and usability of recording technology has progressed since then to what it is today, with the ease of recording high-quality audio available in virtually any package or size.

While the main "purpose" of recording technologies has been to preserve and document events or situations, these technologies can also be used within a more performative context. This was explored extensively during the rise of *Musique Concrète*, which was derived from the concept of "music made with fixed sounds, unconcerned with the origin of the sounds it uses" [40]. This approach took a utility which has previously been relegated to the preservation of sound and deployed it as a sort of performative instrument. This utilization of recorded media as a performance tool is also important to the *Sonic Vessels* method. While these kinds of technologies are in fact used in their original purpose for the sake of documentation, they are also easily used in a more performative context. This was done rather extensively at first with the installation piece *Ephemeral Counterpoint*.

This installation work used 5 open reel tape machines, 4 cassette tape players, and 3 VCRs, all of which had cut loops playing on them. In Figure 3.7, you will see a still from this exhibit. Three open reel machines with extended tape loops of improvised sounds from my longtime friends Bobby Hawk and David Henson are strung up to the ceiling. In the background, two small CRT televisions play back loops from my childhood home movies.

Figure 3.7 *Ephemeral Counterpoint*

The material that was used for all of these loops came from two distinct sources:

1. VHS home movies from my childhood.
2. Improvised melodic lines from my two longest collaborators David Henson (voice) and Rob Hecht (violin, known professionally as Bobby Hawk).

The use of these old technologies offered the ability to present a tangible representation of the conceptual point of memory loss and nostalgia. With physical mediums such as tape, there is a decay of fidelity over time and use. In Fig. 3.8, I have illustrated the degree of audio fidelity loss in these three mediums over the 72-hour exhibit, in which these tapes were looping repeatedly in spliced loops ranging from 1-4 minutes in length. This fidelity was measured by recording a direct line signal from each device at the onset of the gallery and then again at the end of the 72-hour run, in which they were constantly playing and looping.

This was then fed into a spectrum analyzer and each recording was compared against the initial recording. This was done in tandem with my own aural assessment of the perceived fidelity loss, which served as the primary evaluation for the overall loss of fidelity. This approach was not intended to be a strongly scientific endeavor, but instead a mostly aesthetic one for my own curiosity.

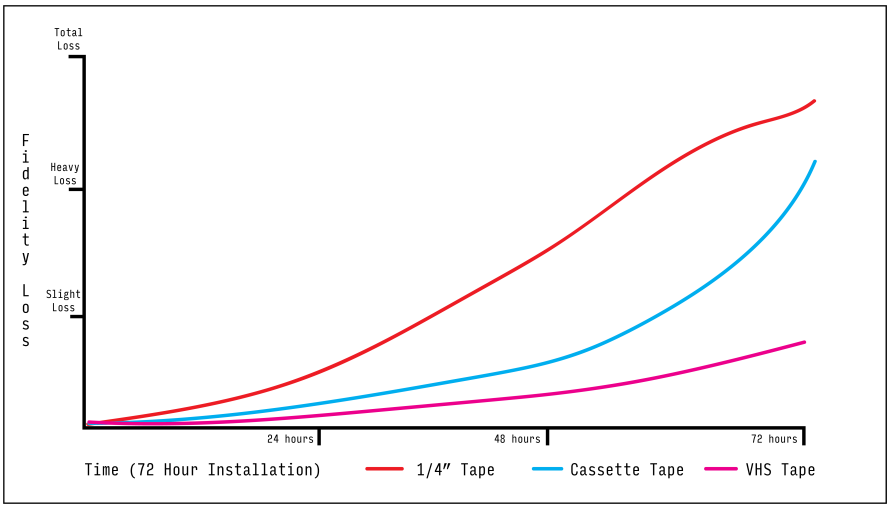

Figure 3.8 Decay Rates of Recorded Media

The main thematic approach was to use recorded media as a vehicle for exploring the inherent flaws of our memories, and how physical documents, such as analog tape, can distort or manipulate these already fractured recollections. On a conceptual level, I find that recorded media which is considered old, such as magnetic tape, presents a perfect analogy for our decaying memories. In an sense, this is also reflected in the concept of utilizing past performance data. As I will discuss further in Chapter 5 with the projects *Phantom Undulations* and *Spectral Counterpoint*, the utilization of previously recorded physiological data can strengthen our experience with this new performance paradigm, wherein the past and present "liveness" of the performers can become intertwined, thereby blurring the lines between when these performances are truly live.

3.3.4 Presence, Intervention, Capacity

When developing a performative setting in which real-time physiological data has a direct effect on the work, the interplay between live performance and detected presence must be done in a flexible and intuitive manner. In the case of this *Sonic Vessels* method, the presence (physiology) of the performers is presented as a stream of data. This data is wholly reliant on the bodily presence of the ones being sensed. Although this does not necessarily have to be done physically in-person (remotely in the case of *Phantom Undulations* and *Spectral Counterpoint*), it is still indeed the physiological liveness of the performer which is being detected. As this is the case, every performance should inherently be unique. Depending on the degree of scaling involved or the amount of intervention on the part of the sonification methods being deployed (bespoke instruments, Eurorack synth, etc), every performance should have a unique character compared to other works. Since this data should in many ways be unique for each presentation, it is the performative intervention which will be used to give some sense of consistency or normalization between performances of the same work. For instance, in every performance of a given piece (let's take *Innermost Echoes* as an example), there are specific instructions given to the performers regarding how to manage and roughly respond to the data-affected elements. In the case of *Innermost Echoes*, the data is controlling note selection and rhythmic content for the robotic koto and LFO speed of the Eurorack modules. In addition to these, specific intense gestures are given to the robotic koto at points in which the performers experience moments of synchrony between their respective data.

Negotiating the intention of the performer against the physiology of the same performer and the other performers on the stage is a large task in and of itself. As trained musicians typically are experienced with how to interact with one another, this is not a completely new phenomenon to tackle. From an early age, most trained professional musicians and amateur/self-taught musicians alike are experienced with how to engage with each other through gestural, visual, sonic, and performative means. However, when one of the "performers" is in fact a robotic instrument, a tape machine, or something which is not even visible, a new dichotomy arises: something which is visible and physical vs something which is heard but not seen as a living being. I posit that this issue is not one which

is detrimental to the perceived or experienced liveness of the performance itself. Instead, it is simply a slight adjustment in approach which is the responsibility of both the performer and the composer (in the case which these are two separate individuals). So much of our performative language comes from responding to the sounds we are hearing in the moment and engaging in the activity of this dialogue, as opposed to the creation of a tangible product [109], and as such the level of difficulty in adapting to this new performative dynamic is not a large concern and will be discussed in greater detail in Chapter 4 and Chapter 5.

In much of the initial works I was part of during my doctoral studies, such as *Boiling Mind*, *Frisson Waves*, and *Sonitecture: Module 1.1*, there was a great emphasis on the perception and response of the audience which was the central part of the physiological data acquisition. Although separating the audience from a live performance is an arguably impossible task as I see it, the focus and core of *Sonic Vessels* is not strongly concerned with the perception of the audience directly. The choice to focus almost entirely on the performer presence as opposed to the audience presence came about for two main reasons. First of all, having spent a great deal of time in early collaborative works which focused almost exclusively on audience data, I found myself having reached a point where my own research explorations needed to have a degree of separation from the previous works. The work we did together had an indelible influence on my early research but I wanted to find a different focus for my own work. Secondly, the more I explored performative methods and compositional applications of liveness, the focus of the work necessitated a more narrow focus on the performer and composer. Of course, the audience will have some kind of experience which could be (and for post-performance analysis often has been) analyzed. However, the focus of *Sonic Vessels* is not to only utilize the audience's data in a performative manner but rather to use this data as a means of further analysis after the fact, and in the case of *Phantom Undulations* and *Spectral Counterpoint*, as a passive integration. In terms of performative intervention and physiology-based interaction, this system is directly focused on the real-time data, presence, and passive communicative physiology of the performers, whereby this approach can allow for new sonic dialogue to arise based solely on those making the sounds. This approach also allows for an in-depth exploration of how this presence-indicating data can be applied to

non-living sonic objects such as bespoke musical robots. The application of this sonification method can allow for an at times unusual and novel perception of the performative experience. When these non-living objects reflect the real-time presence of the human performers on stage, it creates a sort of feedback loop between performers and their own physiology. In other words, these objects are neither independent from nor completely beholden to the performers. The dynamic between these two roles is something that is more thoroughly explored in Chapter 4 & Chapter 5.

In this new approach to performative and compositional dialogue, new roles are inherently going to arise. While positing that one specific method or approach is inherently superior to any other is far from my intention, I would propose that a common factor in much live music could be represented as a predominately one-way discourse. When performing live, musicians and/or performers are presenting their work which is then consumed or experienced by an audience. Whether this is done in real-time, within the confines of a recording studio, crafted at home, or any number of means, the works are typically (though certainly not always) created with the intention of the composer/performer to then be relayed to the audience (see 3.3).

Table 3.3 Traditional Compositional and Performative Flow

Composer	Performer	Audience
Dictates the idea.	Interprets the score.	Experiences the work.
Prepares the experience.	Presents the idea.	Does not intervene.
Determines the concept.	Follows the guide.	Receives both inputs.

What is proposed with the *sonic vessels* approach is to establish a more conversational approach to live music performance and composition, wherein the direction of dialogue takes on a more web-like structure. In this configuration, the flow of intention, presence, and affect is no longer linear or pre-defined, but instead flows in all directions. In some ways, this approach takes some of the agency and control away from the main performers and relegates it throughout all participants (audience, performers, composers, etc). Furthermore, this approach strengthens the presence and utilization of any sound-producing objects which may have a connection, direct or indirect, thereby affording them the possibility of owning an

equal amount of agency as compared to the living people within the performative experience.

An early precedent and influence on this approach comes from the works of the League of Automatic Composers. Formed in the San Francisco Bay area from 1978-1983, this group of experimental sound artists pioneered the early uses of microcomputers [110]. In their own words, "The heart of the work was in physical *bricolage* or *assemblage*, an essentially sculptural musical practice" [111]. While the microcomputers which they used are far from what we have access to today, this practice of assembling objects which would have such an influential role in the work and the conversations within the work has left an indelible influence on the works of many of today's electronic artists, myself included. Another massive shift in the way composers utilize electronics and new technologies came from David Tudor and his explorations into electronics and found objects as musical instruments. As he stated it, "the object should teach you what it wants to hear" [112]. Rather than creating some kind of object with such a direct intention of how it will sound or respond, his belief was more about letting these objects have their own sense of autonomy or intention which you, as the performer or composer, should respond to and allow to take shape naturally. In this situation, the role becomes much more conversational and collaborative between the performer and the object. Through this heightened sense of freedom of autonomy for these sound-making objects, a new dynamic takes shape.

In the web-like structure of this *Sonic Vessels* method, every member of the audience, the performers, the composer, and any sonic objects are communicating in some way with every other object. Instead of a one-way communication, the performative and interpretive dialogue is moving in all directions. This setup affords the possibility of cross-talk and more communal conversations within the performative setting. With this kind of open-ended communication occurring, the roles which were previously often times rigid are made to be much more fluid: the composer is as much a listener as the audience, the sonic objects are as much a composer, the audience are as much a composer, etc. The strict roles that we all play in these performative structures are far more open to interpretation, modification, and exploration.

3.4. Hallmarks of *Sonic Vessels* Performance Works

Every performance within the *Sonic Vessels* approach takes on certain unique characteristics, whether that is in the exact instrumentation, the use of bespoke instruments, the location of the participants, and also the music which is being performed. However, there are certain consistent aspects which I will briefly discuss.

3.4.1 Hardware Setup

The hardware setup for *Sonic Vessels* performance and installation works can vary greatly depending on the needs and intention of the works themselves. However, there are certain hardware elements that have remained consistent throughout my exploration of this concept. These hardware elements are:

1. Bespoke instruments/sound generators
2. Eurorack synthesizers (of varying configurations)
3. Presence-Detecting Means

Although my intention with this method is to create a blueprint upon which other researchers and artists can engage in their own explorations, it seemed much more efficient to restrict the hardware used to a limited setup in order to allow a more focused and thorough study on how these particular objects and tools could be utilized. These specific hardware elements were chosen from a long list of possible objects and proved to have an adequate amount of flexibility while also allowing for this more refined and selective method. Similar studies could be carried out on any number of hardware devices as long as their application could be retrofitted to the methodological approach.

Bespoke Instruments

The utilization and conception of bespoke musical artifacts came about through discussions regarding the different ways in which we could sonify the presence of performers. The main initial goal of mine was to create something that could feel

like another performer in both sound and sight. This is where the idea of making our own instruments began. These physical objects could be controlled and influenced remotely but the physical presence of them adds an added layer of perceptual performativity to them. I spent quite some time during my CalArts years working with the bespoke instruments which are collected in the Machine Lab, a space on campus run by the Music Technology department which has a number of incredible robot instruments such as an upright piano, marimba, percussion, and even a flute box which I co-developed alongside my colleagues. Although my input in terms of the construction and software elements of these were little to none, I spend many hours programming them to perform in a natural way. it was here that my interest in how the performative language of a robot-controlled instrument could better reflect a human performer. Years later, I find myself exploring this in full with the robotic koto that I developed alongside George Chernyshov and Misha Pogorzhelskiy. This robotic koto, which will be discussed fully in Chapter 4, allows for the presence of other performers to drive its own performativity, which in turn affects our own intentions and decisions in the performance. The added visual aesthetic and presence of this artifact brings about a heightened sense of collaboration when compared to using solely sonic representations. Other objects were developed alongside the robotic koto, such as the sonic object in *Phantom Undulations* and the creatures from *Sonitecture: Module 1.1*, but this koto serves as the main bespoke artifact which will be discussed in this thesis. Future plans include extending the capabilities and design of the robotic koto and utilizing other instruments in a similar manner.

Eurorack System

The very nature of Eurorack/modular synthesizers allows for a largely customizable approach to signal routing, not just in the individual modules themselves but in the configuration and selection of modules to populate the cases with. The process of building up the Eurorack system which is used throughout much of my work began in 2020 with the initial purchase of the Synth Voice and Drum Machine systems by 2HP [113] [114]. These all-in-one systems are comprised of much of the basic elements you need to create a small synthesizer and a drum machine, including an ADSR, VCO, MMF and VCA (Synth Voice) and a Kick,

Snare, Hat, and Mix (Drum Machine). Since this was the biggest step I had ever taken towards building out my own Eurorack system, these were the perfect place to start. My previous experiences with Eurorack synthesizers began in 2003 when I purchased my first analog synth, the French Connection keyboard and Spawn synth module from Analogue Systems [115] [116]. This analog synthesizer and controller was commissioned by Radiohead multi-instrumentalist Jonny Greenwood [117] and also used by Alessandro Cortini. The modular patching possible within this setup alone is fairly limited when compared to a more sprawling setup, but laid out the foundational understanding of signal flow which I would delve into later in my career. The next step in my exploration of modular synthesizers came when I attended the California Institute of the Arts (CalArts) from 2015-2017. CalArts has a wonderful modular studio room which has many synthesizers from Buchla, Make Noise, Serge, and Blacet, to name a few. Throughout my time at CalArts, I worked as a Studio Assistant in this modular studio which gave me extended time to experiment with a much larger Eurorack system. Although this heightened my interest in modular synthesis, it wasn't until a year into my PhD studies that I found myself really diving headfirst into curating my own system.

Following the initial purchase of these 2HP systems, I shifted towards DIY synthesizer kits, predominately from UK distributor Thonk. This allowed me to make better use of my funds while also allowing me to learn more about how the circuitry of these modules works. One of the most appealing aspects of modular synthesis is just how flexible they are in terms of setup. It would be rather unusual for two Eurorack setups from two different artists to be exactly the same. The very nature of these setups is that they can be easily customized to the preference and needs of each artist. In my case, the main thing which is the core of the setup is the Expert Sleepers FH-2, which acts as a MIDI-to-CV converter. This allows for any data which enters Max/MSP to then be routed directly into my synthesizer system. My current setup also features a number of modules from smaller synth makers such as Djupviks Elektronik and Zlob Modular. Both of these makers provide unique and esoteric modules which stray away from the more conventional modules. While I do have some of the more conventional ones, populating my system with many unique modules allows the overall use of the system to easily find its own voice. The esoteric nature of the overall system I

have built may pose some challenges in terms of recreating these works exactly, but that is actually a positive thing. It is much more interesting and beneficial if those who would care to implement this into their own work find how the methodology fits within their own personal sonic and performative aesthetic. This thesis can simply act as a guide for how to present it in your own terms.

Presence Detection

Throughout nearly all of my presented works, the core means of presence detection has been made possible through the physiological sensing platform developed by my friends George Chernyshov and DingDing Zheng. This unobtrusive platform consists of a small watch-like wristband that houses the board and chip along with finger probes that attach to two fingers of the user. Through this device, we are able to detect in real-time a number of physiological data streams, including EDA, HRV, and BVP to name a few. Based on the works which I have presented and worked within that have used this system, these wearable devices do not impede the performance flexibility nor do they pose a major distraction from the performance itself. In some cases, these devices will utilize ECG instead of the finger probes to reduce the visual and/or use of fingers, based on the preference of the performer. IN addition to these wristbands, a dedicated wifi router network is used to prevent any issues occurring due to high traffic on public wifi, since these devices transmit the data over wifi to the data processing software which will be discussed in the next section. For a couple of my collaborative projects, different presence indicators have been used such as proximity, gyroscope, and EEG. However, for *Sonic Vessels*, the main presence indication which is utilized comes from this sensing biodata.

3.4.2 Software Setup

The software used for all of these in-the-wild performances stayed mostly consistent throughout all of the performances. They included:

1. Max/MSP.
2. Custom software for the sensing network.

Table 3.4 MIDI Routing and Implementation for *Innermost Echoes*.

MIDI Number (Solenoid)	Pitch	MIDI Number (Actuator)	Actuated Pitch
1	A3	21	Bb3
2	B3	22	C3
3	D4	23	Eb4
4	E4	24	F4
5	C4	25	Db4
6	Bb3	26	B3
7	G4	27	Ab4
8	D5	28	Eb5
9	G3	29	Ab3
10	A4	30	Bb4
11	F4	31	Gb4
12	C5	32	Db5
13	Bb4	33	B4

Table 3.4 shows the MIDI routing scheme for most *Innermost Echoes* performances. The control input method for the robotic koto is done via MIDI implementation. Although the MIDI note numbers used for control have changed a few times throughout the development cycle, it has always stayed within this protocol. Below is a chart describing the most recent iteration of the MIDI protocol. More specific implementations will be discussed with each project.

The control over the Eurorack synthesizer system is also done over MIDI protocol, but this is done across MIDI channels 2-10. A Eurorack module is used to translate the MIDI messages from the laptop into CV signals. My setup utilizes the FH-2 module along with FHX-8CV, FHX-8GT, and ESX-8GT modules, all from the UK-based company Expert Sleepers. This module system allows for my laptop to connect to the main FH-2 module as an interface over USB-C and then send MIDI messages directly in this way. In total, there are 64 possible CV outputs and 64 gate/trigger outputs, all of which can easily accept MIDI CC messages. This flexible and expansive connectivity and control interface affords a vast amount of performative possibilities within the Eurorack system.

The most crucial software which is used in all of these works is Max/MSP. This

software is where most of the control and management is being done. As seen in Figure 3.9, all of the physiological sensing data enters via OSC protocol over WiFi. Max/MSP takes these OSC messages and then deploys them to the control elements of the patcher in either OSC or MIDI protocol.

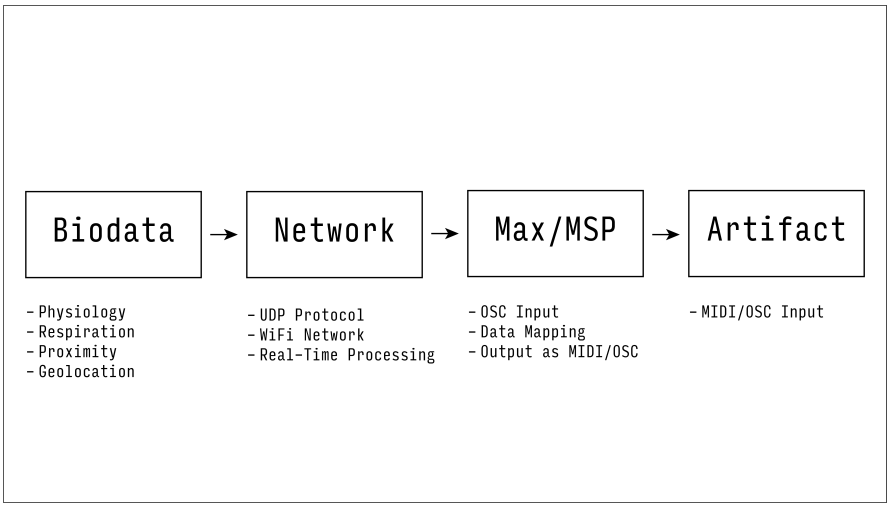

Figure 3.9 Communication of Live Data Within a Performance System

Certain things need to be taken into consideration when deploying this data, such as setting limits, ranges, and applications depending on which aspects they will control or manipulate. These more specific concerns will be addressed within the discussions of the projects themselves, as there are too many variables to discuss in broad terms.

In general, the setup of the Max/MSP framework follows a similar routing to what is shown here in Fig.3.10.

With every performance and every project, the application and utilization of biodata and presence is done in a specific way which accommodates the unique needs of every work. However, the overall path of this incoming data reflects at least in some ways this general mapping. When discussing each of the projects presented in this thesis, a closer look at each project's unique Max/MSP framework will be discussed and presented.

The main method of physiological sensing within *Sonic Vessels* utilized a custom designed sensing platform by George Chernyshov and DingDing Zheng. This platform is comprised of sensing wristbands with electrodes for the fingers and

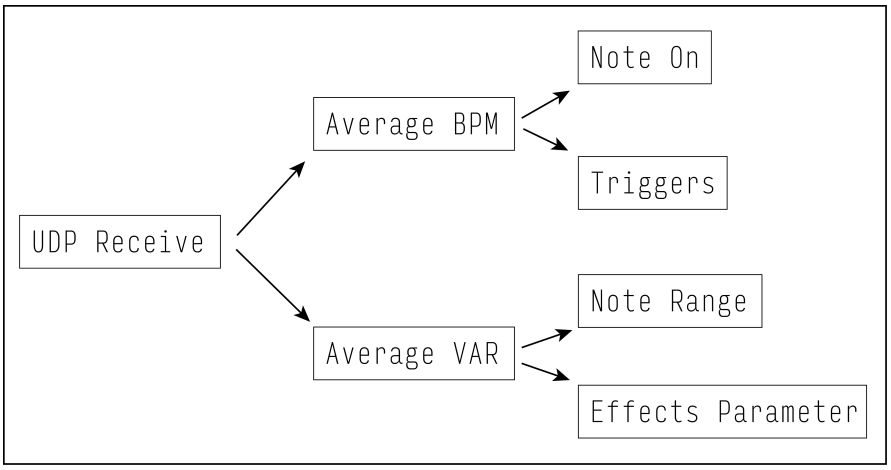

Figure 3.10 General Max/MSP Routing of Biodata

the accompanying software for real-time processing and communication. This software communicates the real-time sensing data to Max/MSP, which then distributes the data to all of the musical artifacts. The approach to determining the form that the data would best appear in Max/MSP was done through a trial-and-error process and was eventually boiled down to two main features: average BPM of each group or participant, and average VAR of each group or participant. The BPM of each group consisted of the averaging of all independent BPMs from each person within an assigned group, while the average VAR was a combination of several biodata features. This was discussed in detail in our upcoming publication titled *Innermost Echoes: Integrating Real-Time Physiology into Live Music Performances* for the TEI conference. Below is a passage from this publication which goes into the details of how we came to decide upon this VAR data:

"Since we cannot realistically establish any baseline excitement or arousal levels in the current settings, we focus on the changes of these parameters signifying increase or decrease in arousal/excitement or a shift in the sympathovagal balance (balance between parasympathetic and sympathetic nervous systems activity). Mathematically it is expressed as the ratio of the previous parameter value and the difference between the previous value and the new value. It can be expressed as RMSSD_USED = NEW_RMSSD / PREVIOUS_RMSSD - 1; where the variable that we use for the performance is RMSSD_USED, NEW_RMSSD is the result of the latest feature extraction and PREVIOUS_RMSSD is the previous value.

Identical calculations were performed on the EDA Phasic peaks-per-minute parameter.

Considering that ideally for this performance we should utilize only one parameter, instead of choosing from all the available metrics, we decided to combine the momentary changes in the number of EDA peaks per minute and the changes in the RMSSD into one variable. In order to combine the two derived metrics into one we used a simple average of the two.

Since it is highly unlikely that the selected features will instantly change by a lot, and each increase will eventually be countered by a decrease and vice versa, such a ratio-based approach allows us to expect the values to be within -1..1 range and be near-normally distributed around zero. While numbers can theoretically fall outside of the -1..1 range, we limit the range to -1..1, as any numbers outside this range most likely are caused by noise. Such extremes were prevented from passing through to the musical artifacts in the Max/MSP software.

Such calculations were done for every audience member every 5 seconds, then the results were averaged for the whole audience and sent via OSC to the artifact system [118]."

3.5. Preliminary Investigations

Throughout the time I have spent developing this methodology, several preliminary works of my own and collaborative works with other researchers and artists have provided a foundational and experimental avenue for my work. These include works with artists such as Stelarc, SenSen Mu, and Mademoiselle Cinema, which cover a broad range of works including performance art, dance, and photography.

3.5.1 Sonic Perception User Study

In November of 2020, we conducted a user study which focused on the listener's perception of a variety of sonic elements. The purpose of this study was to better understand how listeners perceived sonic gestures and what kinds of physiological feedback we would get from these specific sonic gestures. In order to reduce the number of external variables, this study was conducted in near total darkness. The study was conducted inside of the Media Studio at KMD where listeners

were sat in a chair in the middle of the space. 14 speakers and two sub woofers were placed surrounding the listener to provide an immersive soundscape. For the experience, a series of short sonic works were played with no pauses between each piece. The listeners were instructed to make themselves comfortable and try to not focus too hard on any particular thing, just to allow the soundscapes to exist around them.

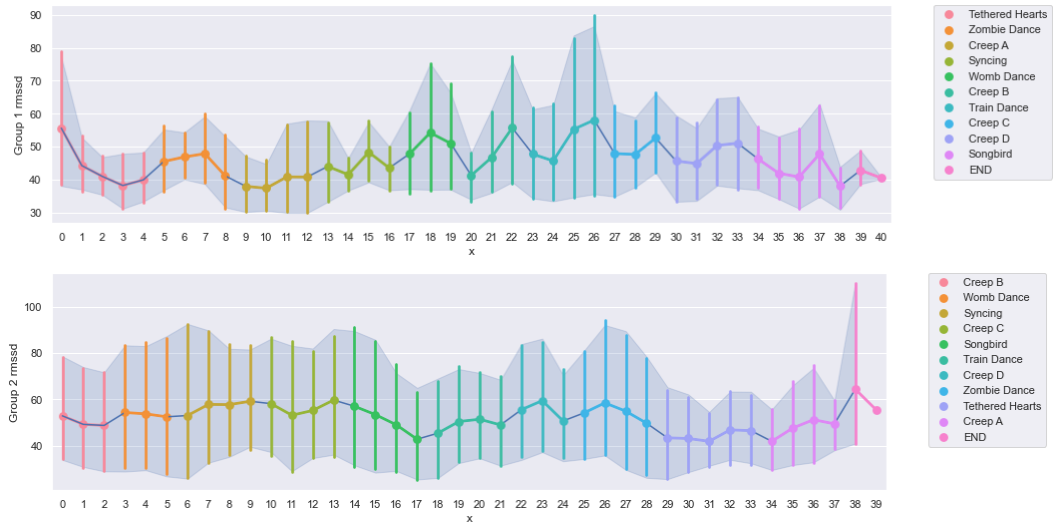

Figure 3.11 RMSSD data for all the participants combined for both groups labeled by the tracklist.

I created 10 music tracks and played them during the study with 2 different orders. They are: Tethered Hearts, Creep B, Creep A, Train Dance, Creep C, Creep D, Syncing, Womb Dance, Songbird, and Zombie Dance. The participants who were assigned to group 1 were asked to listen to the music tracks in the order: Tethered Hearts, Zombie Dance, Creep A, Syncing, Womb Dance, Creep B, Train Dance, Creep C, Creep D, Songbird. The participants were be seating in the dark for 2 minutes of silence at the end of the musical playback. For group 2, the participants were asked to listen to the music tracks in the order of Creep B, Womb Dance, Syncing, Creep C, Songbird, Train Dance, Creep D, Zombie Dance, Tethered Hearts, Creep A. Like the previous group, the participants were be seating in dark for 2 minutes of silence at the end (as shown in 3.11).

I chose these track orders to test a few hypothesis I had. Specifically, I wanted to

explore how perceived moods such as “creepy” and “calming” would be perceived when played back to back, how the synchronization of rhythmic content would be perceived, if vocalizations would have any verifiable effect, and if spatialization would play a factor in the perception of the audience.

1. Creep A: ambient, horror, no rhythm, no voice
2. Creep B: ambient, horror, no rhythm, no voice
3. Creep C: ambient, horror, no rhythm, no voice
4. Creep D: ambient, horror, no rhythm, no voice
5. Tethered Hearts: ambient, no rhythm, calming, voices
6. Syncing: non-quantized rhythms, chill, melodic, no voice
7. Train Dance: semi-non-quantized rhythms, no voice, chill, melodic
8. Zombie Dance: quantized rhythms, no voice, chill, melodic
9. Womb Dance: quantized rhythms, no voice, chill, melodic
10. Songbird: no rhythms, voice, chill, melodic

We processed the delta of RMSSD features of the HRV data (the ending value of the RMSSD minus the beginning value) from the participants while they listened to the music tracks. We ran a one-way ANOVA test for the data set and we found some significance both among the music tracks and among the groups which had different playing orders.

Table 3.5 Changes in RMSSD features between the beginning and end of the four Creep tracks.

Delta Value of RMSSD features from the participants while listening to 4 Creep Music Tracks

Creep Music Tracks	A	B	C	D
	6.711	31.052	4.001	9.853
	-6.719	6.262	3.948	-6.484
	-28.934	27.097	16.122	2.011
Group 1	7.333	7.810	16.176	2.813
	1.817	-4.563	3.510	20.118
	7.692	62.121	11.560	-22.251
	-2.367	-22.243	-8.449	-1.218
	37.065	7.928	-9.096	38.410
G1 Mean	2.8248	14.433	4.7215	5.4065
G1 SD	18.3583	25.55	9.8192	18.1025
	19.639	-21.557	-11.605	2.347
	-2.866	-7.657	19.958	-2.479
Group 2	21.090	4.574	2.764	-30.357
	-3.014	-17.399	8.192	3.079
	30.332	9.923	-5.957	-10.858
	68.920	3.104	3.030	1.316
	17.505	0.042	-5.563	2.895
G2 Mean	21.658	-4.1386	1.5456	-4.8653
G2 SD	24.2924	11.7982	10.5407	12.2814
G1&2 Mean	11.6136	5.7663	3.2394	0.613
G1&2 SD	22.7158	21.864	9.9255	16.0196

- As listed in Table 3.5 there is no significant difference among Creep A, B, C, and D, nor is there a difference between group 1 and 2 for all these music tracks.

- Creep A,B,C,D vs all 6 Calm tracks are significantly different. The f-ratio value is 4.16337. The p-value is .043085. The result is significant at $p < .05$.

- Track Creep A is significantly different from the rest. The f-ratio value is 4.86712. The p-value is .028915. The result is significant at p <.05. Yet, within Group 1 creep A showed no significant difference from the rest while for Group 2 when the participants listed to creep A showed significant difference. The f-ratio value is 7.83947. The p-value is .006497. The result is significant at p <.05. The different results could be caused by the order that the creepy tracks were playing.

- Among all the participants from group 1 and 2 there is a significance between Creep A and Zombie Dance. The f-ratio value is 6.41397. The p-value is .01721. The result is significant at p <.05. The same goes for Creep A and Tethered Hearts. The f-ratio value is 4.61476. The p-value is .040494. The result is significant at p<.05.

- Among all the participants from group 1 and 2 there is a significance between Creep C and Zombie Dance. The f-ratio value is 4.79475. The p-value is .037041. The result is significant at p <.05.

- There is a significant difference between music tracks Songbird and Creep A (the f-ratio value is 5.37174. The p-value is .027994. The result is significant at p <.05) The ending songs comparison among group 1 and group 2 (Songbird G1 vs. Creep A G2), the result is not significant at p <.05.The f-ratio value is 4.36658. The p-value is .056872.

- With Group 2 playing order, the music track Songbird is significantly different from all other tracks.The f-ratio value is 4.04353. The p-value is .047936. The result is significant at p <.05. However, for group 1, the music track songbird did not show comparing to other music tracks.

- With Group 1 playing order, the music track Tethered Hearts is significantly different from all other music tracks. The f-ratio value is 5.46107. The p-value is .021769. The result is significant at p <.05. However, with the Group2 paying order the music track Tethered Hearts did not share the significance over all other music tracks.

Subjective Questionnaire Feedback

All of the participants of the sound affect user study were asked to fill out a subjective feedback questionnaire. This questionnaire was meant to gather a better understanding of their subjective experience in this study and how the setting of the listening environment affected their experience. It consisted of three quantitative questions and four descriptive questions. It was designed based on a 1-5 Likert Scale, with 1 being Not at All/Extremely Easier/Not Engaged, and 5 being Completely/Extremely Harder/Completely.

Table 3.6 The Questionnaire feedback of Participants xxxxx

		N	Q1	Q2	Q3
G1 Mean	Male	4	3.96	2.75*	3.94
	Female	5	3.80	1.80	4.40
	Sum	9	3.87**	2.22	4.19
G2 Mean	Male	6	4.58	1.79	4.46
	Female	3	4.00	2.00	4.33
	Sum	9	4.39	1.86	4.42

** For the feedback on Question 1, there is a difference in Group 1 playing order and Group 2. The p-value is .042 <.05.*
*** With the Group 1 playing order, there is a gender difference in Question 2. The p-value is .034539 <.05.*

We ran a T-test for the first 3 questions' feedback of the questionnaire from the participants. We found significant differences between group 1 order and group 2 order for Question 1 results. The p-value is .034539. The result is significant at p <.05. We also found gender differences within group 1 playing order regarding question 2 answers. he p-value is .042. The result is significant at p <.05.

Discussion on These Results

Based on the results we found, there are a few things which we found to be significant and which helped to guide the ways in which physiological and presence-based data was implemented into future sonic works. First, the significance of songs with non-synchronous rhythmic content was used to sonify elevated levels of arousal in

future works. We also implemented vocalizations in sections where we wanted to embody a significant presence. Furthermore, the order of tracks proved to have an influence on the perception of sounds, which led us to implement incoming presence-indicators in a way which would manipulate macro-level musical and gestural structures in a way that would embody this movement. In other words, the data which we discovered through this study provided the backbone of the sonification methods moving forward.

3.5.2 Iterative Compositional Explorations

One of the first exploratory stages of this method involved an extensive iterative process in which biodata and presence indicators were tested in a variety of situations. The first and main step of this was to gather preliminary biodata from myself and build a native windows app using QT which would loop this recorded presence data. This allowed me to experiment with a biologically plausible data flow as it would reasonably come in during performances. With this in hand, I spent numerous sessions looping this data and applying it to different kinds of applications within the Max/MSP control interface. The primary applications of this data consisted of:

1. Average BPM assigned to rhythmic sounds, tempo objects, and note triggers.

2. Varying data (typically comprised of a combination of pnn50, RMSSD, and HRV) assigned to LFOs, effector parameters, and harmonic ranges.

3. Combinations of these data types applied to macro level elements of the compositions such as harmonic movement, duration of gestures, and textural densities.

In each section of the works I will present, there will be a discussion on the specific iterative process which guided the development of the work. I will give a brief example of this process as it pertained to the work *Spectral Counterpoint*. In this work, which was a remote performance that utilized past and present biodata from audiences in London, Hiyoshi, and Japan, the overall structure of the piece

was three movements. The first movement was generated within Max/MSP, the second movement was generated in the Eurorack system, and the third movement was tape recordings of the previous movements, further manipulated by the Eurorack system. The initial iterative process was focused on establishing the tonal center and sonic characteristics that would be utilized. In the beginning, I improvised numerous hours in conjunction with a native Windows app which was developed by George Chernyshov. This app would replay recorded physiological data of myself and others and allows for a customizable number of participants and groupings. The data which is produced is identical to the ways in which data is sent during live performances, with each group's average BPM and each group's average varying data, which consists of a combination of rmssd and pnn50. This improvisational process resulted in three possible approaches:

1. D Major, triangle waves, drones in the low end, higher melodic fragments.
2. A minor, sine waves, minimal note activation, subtle percussive sounds.
3. Whole tone, triangle and saw waves, sporadic bursts of rhythmic content.

Once I had decided upon these three options, I then spent numerous hours exploring each one and noting the flexibility and playability of each one as they pertained to the incoming data. After these extended iterative sessions, I finally concluded that option 2 (a minor) would be the one that I use for *Spectral Counterpoint*. Although this was not done based on any physiological data response from me or any audience members, it was through the lengthy iterative exploration that I found the most comfort in this particular tonality. This was partially done for practical reasons, in that the principle bass module which I used, the 2HP Pluck, proved to more reliably hit the lowest frequency of A, which was in fact the root note. As a note on this, the reason for the unpredictable behavior of this module when attempting to reach lower notes in other key signatures was actually an oversight on my part. While many of my other oscillator modules operated within a 0-10V range, this particular module actually operates a +/- 5V. I only realized this after the performance, so while the decision was made within the limits of this module at the time, it was in fact my incorrect calibration which caused these issues. Nevertheless, this performance work will still retain the same key signature in future iterations.

With many of the realizations of my works, I utilize my own Eurorack synthesizer system. This system has been slowly built over the past two years, with most of the modules built from DIY kits. There is a wide range of makers within this system, with a heavy emphasis on a few makers in particular whose modules are quite unique and, as classified by diy distributor Thonk, "esoteric". The two most prominent of these makers are Zlob Modular and Djupviks Elektronik. Their modules offer extremely diverse, flexible, and sonically expressive possibilities which have become hugely important to this system I have built. This kind of "esoteric" modular backbone allows for me to reach into far more experimental and unexpected places, but it also comes with some challenges when attempting to offer a clear guide for how other artists/researchers should implement my method into their own work. Therefore, I would like to offer a basic framework for the typical signal flow for this method in terms of modular synthesis and compositional implementation in general. This framework is not meant to restrict or dictate exactly how others should use it, but instead give a clearer idea of the macro view of my own implementation. The general flow of signals can be seen in Fig.3.12. While keeping in mind that this is simply a basic routing structure, what is shown is how biodata comes into Max/MSP, is then sent into the Eurorack system as control voltage (CV) via a MIDI-to-CV converter (in my case, the Expert Sleepers FH-2), and then dispersed to specific parameters. Typically, this would be average BPM going to things such as clocks and triggers, and average VAR data sent to the pitch cv and lfo. Once these are implemented, the signal flow is fairly standard practice in terms of modular signal routing. The exact implementation should be done with the intention of the composer/performer, but this general routing is seen throughout all of the works I will present. Much of the decisions I made regarding these routing parameters was based on the closeness and overall idiosyncratic nature of the data when compared to the final output source. For instance, having triggers placed on the pitch control would likely produce no real results as the pitch control simply looks for a wide range of control voltages, whereas the average BPM is giving out consistent triggers as it is. Ultimately, this general routing came from an initial implementation which was then iterated upon many times until a comfortable framework was established which would allow me to more freely compose and perform without having to concentrate too

much on the technical aspects of the implementation.

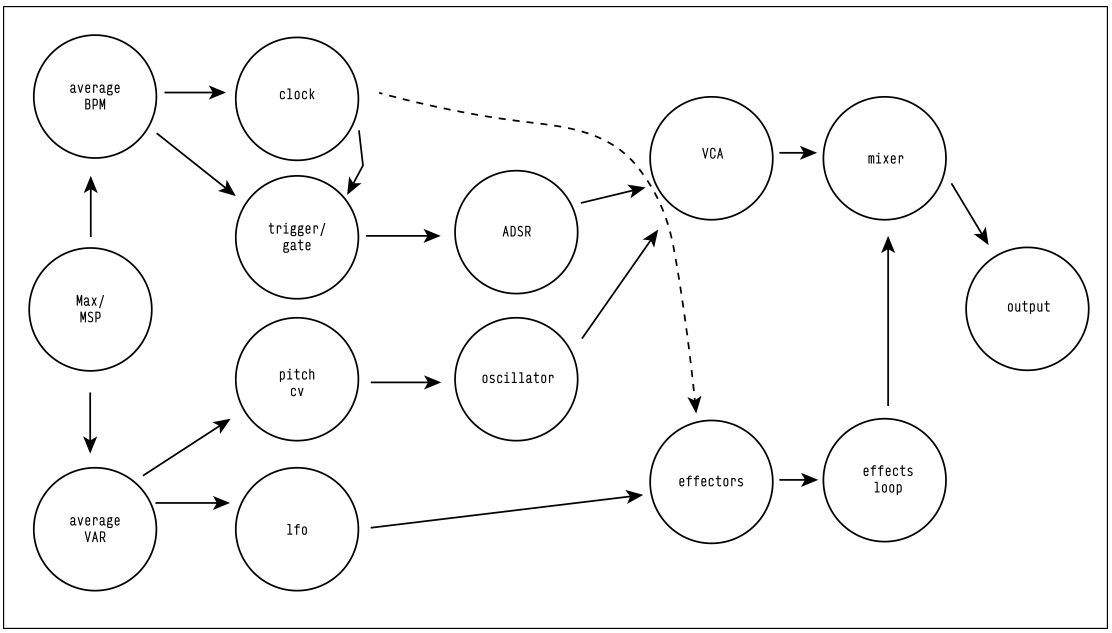

Figure 3.12 Basic Signal Flow of Biodata and Eurorack

3.6. *Sonic Vessels* Categorization

The *Sonic Vessels* methodology which I have presented is a far-reaching method which focuses on new performative and compositional dialogues which are centered on the presence of those involved in these works. Within the larger scope of this method, there is a classification which can break things down into two general realms of creation:

1. Momentary Vessels: Experiences which are occurring here and now.
2. Transient Vessels: Experiences which occur within and outside of the present time and space.

Momentary Vessels

These experiences are rooted in the present place and time in which they are occurring. This is strongly exemplified through the performance work *Innermost Echoes*, which will be discussed in full in Chapter 4. With these works, real-time data and presence are utilized in the music and performance. The place in which these performances are occurring is crucial to the experience. The main underlying concept of them is to utilize "the here and now", which can only happen in this moment. Although documentation has taken place during these performances, it is done in a strictly utilitarian manner. They serve simply as a document of what occurred.

Transient Vessels

These experiences attempt to move outside of "the here and now", and question what it actually means for these works to occur live. The time in which a performance takes place is not the only occurrence of them, but instead one moment in time which blends with other moments both past and future. Two examples which will be discussed further in Chapter 5 are *Phantom Undulations* and *Spectral Counterpoint*. With both of these works, the presence of the composer, performer, and/or audience was used as a means for showing the liveness of these respective individuals at one point in time. This time is then occurring at a later point, which is able to blend in with and collaborate with the current present. In other words, every instance of these works is a part of a larger chronology of performative presence.

Chapter 4
Momentary Vessels

In this section, I will break down the first categorization of Sonic Vessels, which I refer to as "Momentary Vessels". This approach is centered on the creation of works which occur in-person, in real-time, and utilize the current or present liveness. In other words, these are based on the "here and now". A main driving factor of these works is to explore what kinds of dialogues, expressions, and interpretations can occur when our real-time presence takes on a performative role of it's own. By placing this presence or liveness into it's own sonic and expressive body, we allow it to become a slightly independent but not wholly separate extension of the performers whose biodata is driving these presence indicators. For instance, when the biodata of two performers is being sonified and expressed through a robotic instrument, this instrument represents an interesting and oddly complex role. Is it an extension of the performers themselves? Is it something that has it's own sense of autonomy? Is it the embodiment of the performers as a whole? Do these sonification objects favor or rely more on one than the other? These questions and others will be addressed through the primary project titled *Innermost Echoes*, a live performance work which utilized a robotic koto and Eurorack synthesizers as the main sonification method for the presence of two performers: Aoi Uyama on koto and myself on Eurorack synthesizers (and occasionally guitar and bass).

4.1. *Innermost Echoes*

The overall concept of *Innermost Echoes* is to observe, exploit, and record the physiological presence of the performers and embody this data into a robotic instrument. In typical live performances, especially in improvisational musics,

the often unspoken dialogues between performers is a vital part of the resulting performance. Improvisation can be seen as "the expression of human design or intention" [24]. Thus, as the performers are expressing their own intentions, they are also concurrently responding to these intentions which are sonified through a robotic instrument. This begs the question on what or who the performers are engaging in a performance with. Is it an object which is simply mimicking their own intentions, or does it introduce some new form or entity which is neither beholden to nor free from the performer's influence? I do not seek to definitively answer this question, but rather present this as an open-ended observation upon which performers can explore and deduce for themselves what this meaning is for them. Although each performance of *Innermost Echoes* is unique in the performance works and at times instrumentation, the overall approach to utilizing physiological sensing as a benchmark for performer presence is consistent.

4.1.1 Robot Koto Design

The main artifact which we used to sonify and present our real-time presence in this work is a bespoke robotic koto. This artifact was designed around an old used koto which was purchased from Hard-Off and outfitted with 13 solenoids, 13 linear actuators, and a custom-designed circuit board. The final design of the first version of this object was the result of a year-long iterative process of testing various solenoids and actuation methods, which finally led to the final V1 instrument. In Fig.4.1, you will see the overall layout and components of the current version of the robotic koto.

One of the most unique factors of this robotic koto when compared to a traditional koto, besides of course the actuators, is the fact that there are two sets of bridges instead of the traditional single set. This was necessary as a means of raising the strings high enough to fit the solenoids underneath the strings. This additional set of bridges effectively reduces the tonal range of the koto by shortening the overall resonant length of every string. Additionally, pulling the strings from underneath the koto at the same place for each string was done so as to allow us to know that every string would be pulled at the same amount. Since the linear actuators which are pulling the strings are all identical, we knew that setting the metal strings at the same tension would allow them to pull until the string reaches

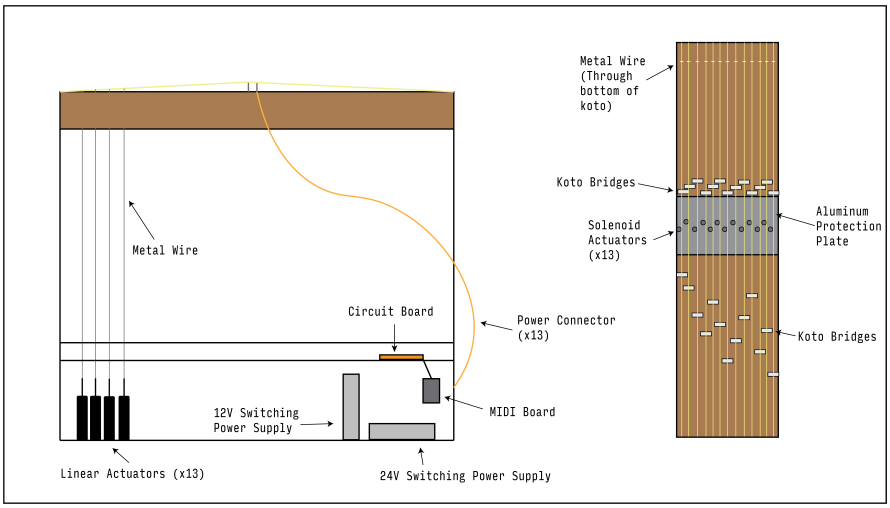

Figure 4.1 Layout of the Robotic Koto

the body of the koto without attempting to pull any further to avoid damaging the instrument. This also presents a slight reduction in the expressive possibilities by only allowing for a detuning of approximately one half step. In traditional koto performances, the range of this string bend is quite large in comparison.

The new version of the robotic koto is already underway and will be presented in mid-2024. This new design, conceived primarily by Michael "Misha" Pogorzhelskiy, will do away with much of the bulky stand which it currently has and will actuate everything from above the strings. This will greatly expand the expressive capabilities of the instrument and allow us to achieve sounds and gestures which are closer to a traditional koto. Although the aim is still to find new ways to utilize the instrument, having the ability to mimic traditional sounds in a more convincing way will expand this setup greatly.

4.1.2 Max/MSP System Design

As with most all of the works I present throughout this thesis, the main control framework of the incoming biodata is designed using Max/MSP software. This visual programming language allows for a fully customizable framework to take in incoming data, route this data to both internal and external objects, and fully control all musical artifacts of the performance works. For *Innermost Echoes*, this

Max/MSP system design was comprised of two main sections:

1. Routing and manipulating the incoming physiological data.
2. Outputting control parameters for external musical artifacts.

All of the incoming physiological data which was being detected from the performers was done over UDP/OSC protocol. The main object within Max/MSP which handled this was the "UDP receive" object. This object takes in all of the data which is sent on a specific port and makes it readily available within the software. Once the data passes through this object, the individual pieces of information were routed independently based on the data type: average BPM of each group and average VAR for each group. The BPM is exactly what is looks like: an averaging of every independent heart rate within a given group. The individual heart beats were also available within this data stream but issues with CPU usage when dealing with so many streams within Max/MSP led me to focus more on the average rates almost entirely. The VAR of each group consisted of a combination of EDA and RMSSD features, which was discussed in length in 3.4.2. To summarize, numerous aspects of both of these features were averaged together to create a more stable and usable varying data point which would give a solid indication of the overall state of these features while reducing the number of streams to handle within Max/MSP.

When it comes to the specific routing of the incoming data to the sonic artifacts, this evolved over time but stayed relatively close to the original setup. This first iteration of this Max/MSP patcher came about during the process of building the first functioning prototype. This prototype consisted only of one solenoid which would strike one string on the koto. The basic framework for this patcher was to route my heartbeat through a "select" object, which looked for the number 1, and would output a bang when this occurred. This bang would then trigger a "message" box with the text "1, 127", which would then be sent to a "noteout" box. Finally, this "noteout" box would output the MIDI message for note number 1 with a velocity of 127 (maximum velocity). The software for the robotic koto was designed so that the solenoids only needed to receive a note-on message and would disregard/not need any note-off messages. Once this seemed to work, we tested to see how quickly we could actuate this single solenoid without overheating

or overloading it. By designing a simple slider attached to the output speed of constant triggers, we were able to determine that a note-on message every 20ms was sustainable for upwards of 10 minutes (much to the chagrin of our lab mates who had to listen to a solenoid firing at 20 times per second for 10 minutes straight).

The linear actuators used for bending the strings were tested around the same time as the solenoids. As opposed to the note-on approach to the solenoid, the linear actuators use a note-on message to retract (pulling the string against the body of the koto) and a note-off message to release (allowing the string to return to it's original location). The software for the robotic koto control board dismisses any repeating messages that occur within less than 20 ms to avoid any issues, but the speed of the linear actuators are much slower than this. Instead of completely dismissing messages during a retraction/release, the linear actuators were capable of maintaining a relatively precise middle-ground if toggled in the middle of an actuation. However, the perceptual affect of this microtonal bend was too minimal to utilize is most of the works presented. Once these two elements were tested and construction on the rest of the actuators had begun in full, I began to design how all of these actuators would appear within Max/MSP. In the end, the choice was made to keep all of the koto actuations on MIDI channel 1, and give notes 1-16 to the plucking solenoids and 21-36 to the linear actuators for bending. This gave us three extra notes for each actuation type in case any of them had issues or needed to be changed out on-the-fly. The routing of the linear actuators was nearly identical to the solenoids with an added "message" box with the note-off command.

4.1.3 Eurorack System Design

For this work, the presence implementation in the Eurorack system focused on three main components:

1. Applying average BPM of the performers to triggers sent to the ADSR modules.

2. Applying average VAR to note selection and parameters within the effectors.

3. Increased activity in both triggers and parameters when synchrony was detected between performers.

Each of the oscillators which were used would receive a trigger based on a division of the average BPM of the performers collectively, as well as occasionally on each individual performers BPM. This was left open as a performative decision due to the sometimes repetitive nature of this averaging method. For instance, if the only BPM to be used was the average, this number would generally stay within a certain range and not deviate too strongly away from a consistent tempo. To integrate more expressive possibilities with the tempo application, a beat division tool was designed within Max/MSP which could seamlessly switch between the direct average BPM and +/- 32 divisions of this BPM. This was made available for the average of the group as well as the individual. Furthermore, each of these discreet BPMs was able to be integrated simultaneously, thereby allowing for much more expressive use of BPM. One key example of this was in the song "Lioness", in which the average BPM would control a single oscillators ADSR while the individual BPMs would gradually trigger their own. The song would culminate in four total BPM threads (the averaged group, and each of the three performers), with each thread producing several additional threads of triggers based on subdivisions of this. The end results was a cacophony of triggers which gradually became a monolithic structure.

4.1.4 Iterative Compositional Process

The development of the compositional and performative language of this work was rooted mostly in semi-structured improvisations. These improvisations started with a basic setup of Max/MSP, which was controlling the bespoke robotic koto. The first step in this process was to establish the main tonal center for the instrument itself. Due to the limitations in tonal range caused by the secondary set of koto bridges, it was decided that the main tonal center would be A minor/C Major. This was mostly due to the ease of having a droning tonic as the lowest possible note. The tuning was mostly centered around A minor/C major, with the exception of an Ab3, to allow for harmonic minor gestures. Once this tonal center was established, I began by making numerous gestures in Max/MSP, which

would communicate via MIDI to the robotic koto. This was done to become more familiar with the somewhat unusual sound of this robotic instrument. In addition to the unusual sound caused by the clicking of the solenoids and occasional pulling of the strings from below, performing gestures which were more rooted in electronic music than traditional Japanese music also required a considerable amount of time and care to explore. This process continued for several months, and was greatly aided by the collaborative efforts of Aoi Uyama, the principal koto player in these project. Her numerous years of professional koto performance and study contributed greatly to the understanding and utilization of this robotic artifact. After several months, there were a number of gestures which seemed to work well, and these gestures would end up becoming the foundation for our first live exhibition at ANB in Roppongi.

The next step in the process was to begin incorporating the Eurorack system into the mix. Since much of the groundwork for the robotic koto was already there, I began by finding sounds and gestures within this synthesizer system which would not only compliment the robotic koto but also serve as a way of enhancing or even manipulating the perception of the instrument itself. These early trials were spent mostly on working out which modules could produce complimentary sounds for the koto, which in the end, consisted of three main sound-generating modules: the Zlob Modular Dual VCO, the Jolin Labs Tabor, and the Djupviks Electronik Bunker Archaeology. This combination of a dual oscillator (typically using one triangle wave and one sine wave), a chaotic avalanche oscillator, and a reverb which could feedback onto itself, offered more than enough room to explore performatively and compositionally. Once these were established as the main core group of modules, additional modules were included to round out the sound, such as additional delays and LFOs. This would then begin the next round of iterations, focusing more on a fuller improvisational approach. Aoi and I would setup our equipment, decide on how we would begin and end this improvisation, and then let the presence and sounds guide us through it. While not all of these iterations would produce ideas which would become a live performance, they all contributed to the greater understanding of this performative system and how we could express ourselves in new ways with it.

4.1.5 ANB Tokyo, June 2022

In June of 2022, the first iteration of a work titled *Innermost Echoes* was debuted. This work consisted of two main components:

1. A nightly performance including a professional koto player Aoi Uyama, a Eurorack system performed by myself, and a robotic koto which was guided by our real-time physiological data.

2. A daily gallery installation in which the robotic koto and Eurorack system played a variety of programmed musical works which were affected by the recorded data of our previous performances.

Figure 4.2 *Innermost Echoes*, June 24-26, Roppongi

This exhibit lasted from June 24-26, and included three performances and three days of daytime installation presentations. While we did not get any audience data or questionnaires for this exhibition, we were able to gain some valuable insights from the first public presentation of this on-going performance work.

The presentation of *Innermost Echoes* was broken down into four different yet inseparable sections:

1. The physical design of the robotic koto, which involved the use of solenoids to pluck the strings, linear actuators to pull the strings down from the bottom, and the antique and vintage visual aesthetics we decided to utilize.

2. The methods of recording the performers' real-time data and utilize this data in the main software which was used (Max/MSP).

3. The musical considerations which had to be taken into account while composing for this setup, which involved an extensive amount of care in deciding which notes to tune the koto to, how to fully utilize this limited number of strings, and how to guide this tonal center in a lyrical and meaningful manner.

4. The performance design, which involved parts of all three design paths while also developing it's own importance as the main means of presenting this work publicly.

In the debut public exhibition of *Innermost Echoes*, we presented our concept through an "in-the-wild" exhibit which occurred on June 24-26 at ANB Tokyo in Roppongi, Japan. In this exhibit, the robotic koto was situated at the far end of the exhibition space surrounded by warm Edison-style bulbs. Directly behind the robotic koto was the Eurorack system in addition to several laptops required for the input and distribution of the sensing data as well as control of the robot koto.

We presented three improvisational performances in which our real-time physiological data was used to control the lights, the gestures from the robot koto, and many parameters within the Eurorack system. This data was taken via a sensing wristband which includes sensors which can detect heartrate, HRV, EDA, and a slew of other data points. For this initial performance, we focused on heart rate. This data is sent wirelessly to a laptop which acts as the main server. This server laptop then sends out the heart rate data to another laptop via OSC which is running a custom designed Max/MSP patcher. This patcher receives out heart beats and then utilizes those in several different ways. First, each individual heartbeat is used as a trigger which can be sent to any number of Eurorack inputs as well as a signal for the koto to play a note. Secondly, Max/MSP detects when there are discreet changes in the speed and rhythm of the heartbeats and uses this indication to trigger a selection of patterns which are pre-defined. Lastly, heartbeats are collected into a pool of triggers within Max which are sent back out in a somewhat chaotic manner, resulting in intense and frenetic musical gestures. All of this data is able to be routed and utilized in a performative manner, thereby

allowing the performers to use this data in a more intentional way. The performative content that comes from the data is neither fully determined by the data nor is it dismissive of it. Rather, it is utilized as more of a set of gestures which can be used in whichever way suits the performance best. As seen in Figure 4.3, the overall flow of data consisted of physiological sensor data which was collected in the sensing software, sent via OSC to the Max/MSP patcher, and then deployed to the robotic koto via MIDI and the lighting via OSC.

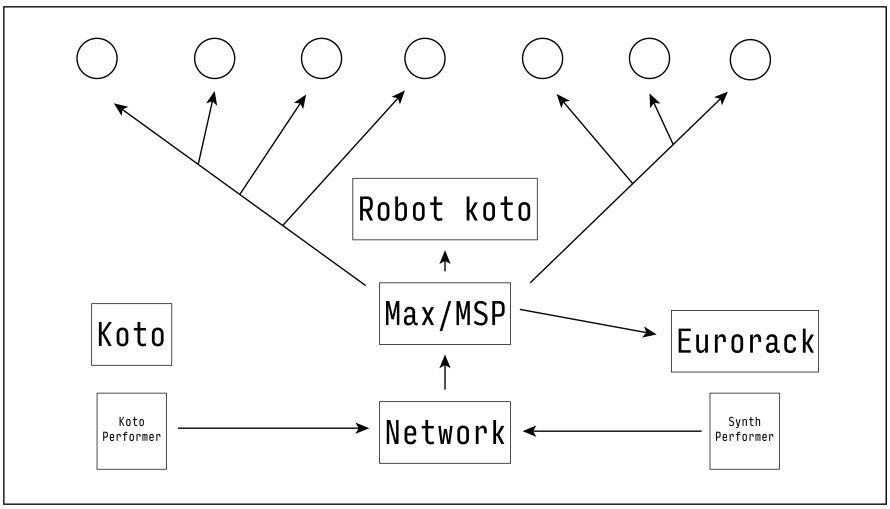

Figure 4.3 Data Flow for *Innermost Echoes* Premiere

Throughout each performance, the resulting data stream is recorded in Max/MSP in the form of OSC messages. All of the raw data events which occurred in the performance are recorded and can then be looped back the following day. We were then able to use our data from the previous night to give some sense of variety and life to the following day's installation. The material which was used during the daytime installations consisted of an arrangement of the Ukrainian National Anthem and a series of loosely composed preludes. The recorded data was used to determine changes in the tempo and selection of which pre-composed preludes would play and in what order they arrived.

The way in which this work was presented offers two distinct yet somewhat inseparable forms of public exhibition. Every evening, we gave a live improvisational performance which offered us the chance to utilize our physiological data in a real-time setting. On the other hand, we were able to re-use that data as

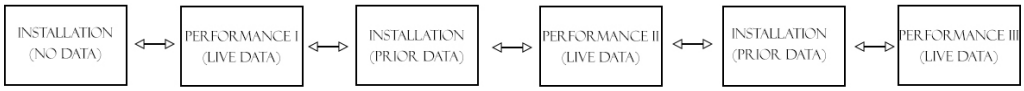

Figure 4.4 Biodata in Installation and Performance of *Innermost Echoes*

a means of integrating our previously recorded data into the following daytime installation (no data was used for the first daytime installation). Fig.4.4 shows the flow of recorded and real-time biodata as it was used in this presentation. This approach to re-using the previously recorded data inspired me to pursue a few upcoming projects which will take this idea and expand upon it greatly.

Prior to these performances and installation settings, I anticipated that the recorded presence in the daytime installations would have a directly reflective feeling to it, especially for myself and Aoi Uyama, whose recorded presence was driving the robotic koto. However, this turned out to not be the case. What occurred in this application was not a directly recognizable implementation of our liveness but instead presented some kind of abstraction or blurred memory of what happened the night before. For instance, in the first recorded playback (the second daytime installation), the tempos were noticeably faster than they were in the second performance (third daytime installation). While the exact reasons for this are not fully analyzed or determined, my guess is that the correlation between a faster average BPM and the heightened feeling of nervousness in myself when comparing the first performance with the second seem to have some kind of influence on it. Despite not having the exact outcomes that I was expecting, this suspicion of a sort of "nervous sonification" gave me a much more interesting idea than I expected. This system does not have to present expected liveness or expected sonification, but rather can allow for these moments to exist as snapshots of these live performance moments. Rather than trying to present how a feeling "sounds", these moments can be abstract documents of the liveness of performers, which will in turn present new experiences that do not have to be actively understood. All of this allows for more interpretive introspection and personalized experiences of everyone involved.

4.1.6 Media Studio/NIME, May 2023

In May of 2023, we held two performances in the Media Studio at Hiyoshi Campus which was filmed and shown for the New Interfaces for Musical Expression conference (better known as NIME). This work was selected to be shown under the Music track at NIME in Mexico City, but issues with transporting the robotic koto led us to perform here in Japan and present a short documentary performance at the festival. In this performance, we invited a guest koto player Kozue Matsumoto, who was visiting Japan at the same time. In terms of performance structure, this was the most planned out one we had given at this point. While there were still quite a lot of sections which were fully improvised, we also presented more structured sections than in previous iterations.

The setlist for these performances were the same each time, and will be discussed in more detail in the coming chapters. These songs were tentatively called:

1. Interlude
2. Ringing
3. Traditional Japanese
4. Chorale
5. Lioness

For each song, there were varying degrees of improvisation and physiological data implementation, all of which was pre-determined beforehand. This ensured that all three of us performers were on the same page and aware of how and when our data was being utilized.

One of the main differences between these two performances and the previous Roppongi gallery exhibit was that we were aware of the fact that our performances needed to be recorded and presented at the NIME conference. With the AND Tokyo performance, there was no focus on the videography or documentation side of things. We simply set our equipment up and performed. This focus on documentation and preservation of the performance for future screening seemed to add a certain degree of intention and planning to the overall approach of this

work. We also had no installation components to this performance, so this also distinguished in from our previous performance in that sense. Overall, I would say that this performance was much stronger in terms of performative awareness and intention but presented new issues in improvisational awareness and expectations from the robotic koto sonification, which will be discussed further in Chapter 6.

4.1.7 Bar Transit, July 2023

In July of 2023, we held another live concert at Bar Transit in Hiyoshi, Japan. This performance was the first time in which the third member of our group, Juling Li, joined us on erhu, a Chinese stringed instrument. This was also the first time that we fully implemented the beta version of the adaptive score. Of the seven songs performed, three of them were taken from our previous concert (titled "Ringing", "Chorale", and "Lioness") while four new songs were added (an opening song, a new traditional Japanese improvisation, a Eurorack improvisation, and a predominately vocal song).

This performance was in some ways in between the previous two performance settings. Like the first ANB Tokyo performance, it was intended for the moment and not for a video recording. However, it was also much like the Media Studio performance in that it was a performance only and not in any way an installation presentation. In general, the focus was more about the responsive score and the direct interpretation of the performer data via robotic koto sonification and visual score.

4.2. Discussion

As I discussed in Chapter 1, my approach to the evaluation and validation of my method consists of qualitative analysis which is supported by and intertwined with quantitative data analysis from the major public performances and a lab study on sound perception which served to guide the implementation of the perceived presence. Here I will present my findings and present how these serve to validate this method as a novel form of sonic performative expression.

Before going into the details on the latest studies and performances I would like to discuss and present some evidence of the validity of my approach to the

evaluation of such a work. Using traditional scientific quantitative approaches for evaluation of artistic works or characterizing experiences can be rather problematic. Such works would traditionally be evaluated through qualitative means, such as interviews, or are judged based on personal opinions of other experts from the field. If the interest from the professional community and independent artist is evident for just looking at the number of artists who have been and will be involved in this work, simply presenting some interviews and expert opinions to demonstrate the validity of my concept falls short of the necessary hard evidence that this work requires. Luckily, since this project is heavily reliant on the use of physiological data, this data can be used as additional evidence to back up the results of the interviews and characterize aspects of the experiences in a way that qualitative subjective methods cannot.

In order to validate this work, all of the data acquisition and analysis were performed in a double-blind manner. This means the participants were never explicitly explained what exactly the investigators will be looking for in their data, and the investigators did not know anything about the details of the experiences and motivations for the artistic decisions. This way, by finding the statistically prominent anomalies in the physiological readings and then referencing them to the audio or video recordings or the interviews, we can be more certain that the exact moments of the performances that stand out in the data can be thoroughly analyzed and explained. By approaching the evaluation from this angle, this thesis, while being related to art, sound, and music, can be also evaluated from a more scientific perspective than is customary. The following sections 4.2.1, 4.2.2, and 4.2.3 contain portions that are to be published in the Eighteenth International Conference on Tangible, Embedded, and Embodied Interaction (TEI '24), February 11–14, 2024, Cork, Ireland, under the title *Innermost Echoes: Integrating Real-Time Physiology into Live Music Performances* [118].

4.2.1 Media Studio, May 2023

On May 19th 2023, two performances were given at the Media Studio in KMD's Hiyoshi Campus. These two performances were recorded and presented at the NIME Conference in Mexico City on May 31st-June 3rd. For these two performances, all audience members and the three live performers were wearing phys-

iological sensing wristbands which recorded their data. The sensing data of the performers was implemented into the robotic koto and Eurorack synthesizer for the second performance, allowing us to compare the results of the use of biofeedback versus a performance without such a system. Below is an evaluation and analysis of these performances.

Physiological Data Recording

In order to support our choice of the physiological data metrics we present the data from the first performance as an example. Although the focus of this thesis is the conceptual framework and methodology, it is necessary to exemplify and explain the choice of the physiological data metrics which are being utilized. We modeled some of our data analysis methods after the performance analysis found in a related study which analyzed the data from audience members of a dance performance [119] as well as our own sound perception study.

Figure 4.5 Summary data from the first Performance. Top: RMSSD metric of HRV of all subjects, outliers with Z-score over 1.5 are removed. Bottom: number of Phasic EDA peaks per minute for all the subjects.

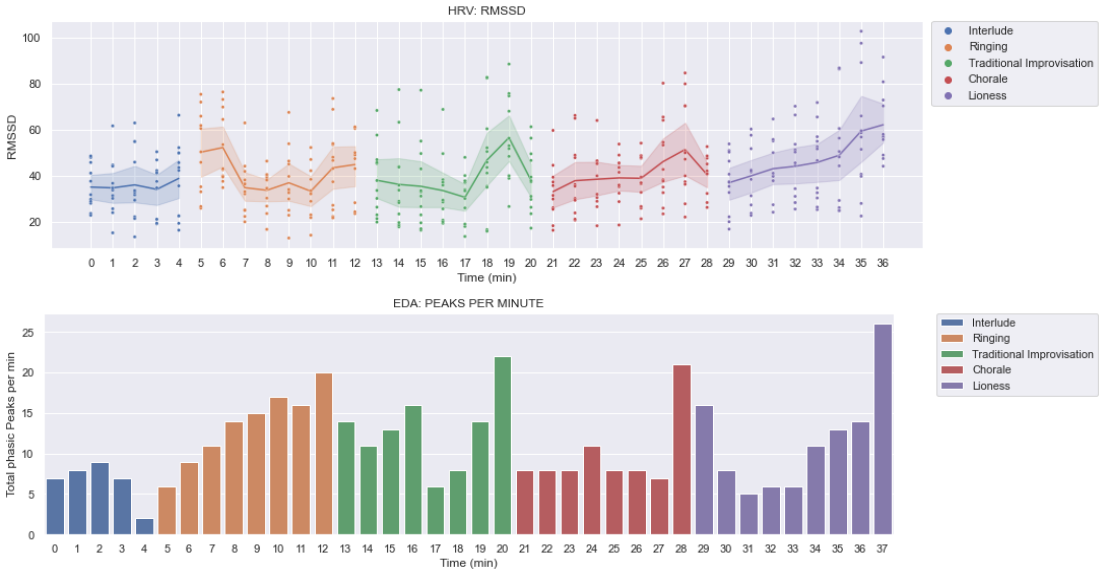

Figure 4.6 Summary data from the second Performance. Top: RMSSD metric of HRV of all subjects, outliers with Z-score over 1.5 are removed. Bottom: number of Phasic EDA peaks per minute for all the subjects.

Heart Rate Variability Data

As shown in Fig.4.5. Top, we recorded Root Mean Square of Successive Differences (RMSSD) between consecutive heart beats in milliseconds as a metric of heart rate variability. It is known to be correlated to parasympathetic nervous system activation, meaning that the increase in RMSSD can be attributed to a more calm or relaxing experience. In the presented data we can clearly identify an increasing trend towards the end of each song. Average RMSSD in the beginning of all 5 songs is 48.82 (STD: 13.77), while in the end it is 58.29 (STD:14.45). Two-ailed T-test shows significance with p=0.001. One interesting point in the HRV data can be seen around minutes 5-8, in which the audience's HRV gradually drops down together, signifying a less relaxed state. These moments correspond to the gradual introduction of each performer (robot koto, then guitar, then the koto players).

Electrodermal Activity Data

In the EDA data shown in Fig.4.5 bottom, we clearly see an increase in the EDA activity at the end of each song. Abnormally high activity is observed at minutes 1, 11, 18, 26 and 31 (Z-score over 1.5). Interestingly, most of them occur on the transitions between the songs (minutes 11, 18, and 26). These three data points can be attributed to the audience clapping and the noise it causes. However, the sudden increase in EDA activity at minute 1 matches the timing when the robot koto starts to play. Minute 31 corresponds to when the robot koto began to play at an accelerated rate. Each of the 13 solenoids gradually started to activate faster and faster, until all of them reached 20ms speeds. This gesture lasted roughly 1 minute and then gradually faded out at the end, and is reflected in the analyzed data.

Findings

Beyond the empirical data analysis we conducted showing certain verifiable aspects of the musical performance itself (introduction of new instruments, dynamic peaks, etc) which were not based on the *Sonic Vessels* method, we found some clear evidence that shows the novelty and strength of the method. Based on our

post-performance analysis, we found strong evidence to show that the implementation of the *Sonic Vessels* provided a more engaging experience. We can show this by presenting two identical performances, with performance 1 not utilizing any physiological data and performance 2 utilizing the performers live data. One of the key findings was a very significant. We also found evidence in the data to show that the implementation and utilization of the bespoke robotic koto caused a verifiable response from people. Below are the significant findings from these performances.

1. Based on the heart rate variability data we can note that the HRV metrics associated with the parasympathetic nervous system activation for the second performance are lower that for the first. For example, the RMSSD value throughout the first performance was found to be on average 51.63, however in the second one it was much lower (41.22). This difference was found to be statistically significant with p=4.78e-23. Within the neurovisceral integration and emotion regulation model, such a drastic decrease in RMSSD signifies the lower level of the parasympathetic activity, implying that the audience was feeling more lively and engaged/excited during the second show.

2. In the third song, which is a fully improvised song in a traditional Japanese style, the RMSSD and EDA of the performers was applied to the effector parameters and delay time of the Eurorack modules in performance 2, while in performance 1 no data was applied. You will notice that in performance 2, when performer data was applied rather vigorously at the 17 minute mark, the RMSSD and EDA values have a prominent spike (z-score of 1.9811) that was not present in the first performance.

3. In the final song, the RMSSD seems to progressively increase for performance 2 while in performance 1, it moves downward before it moves upward. In this instance, the data was being applied to average BPM of the performers and the note selection and pattern speed was attached to the robotic koto, which in turn guided our live performance choices. Towards the end of the song, the timing of the koto became non-quantized and aggressive, and mirrored much of the rhythmic content which was shown in our Sound Affect Study

to produce a rise in engagement, which is reflected in the EDA data, with the spike at the end of the second show being much more prominent.

4. In performance 2 "Ringing", the song was started with the incorrect koto tuning. We reset and began the song again, and in these graphs, you can see that performance two begins rather high and then sharply goes down, possibly signifying the activation of the sympathetic nervous system, characteristic for surprise or discomfort.

This data suggests that there is the potential for a positive outcome when performing with physiological data, even though the application may not be explicitly understood by the audience. Furthermore, this approach of physiological data acquisition both as a means of analysis and for performative intervention proves to be successful based on our findings. None of the performers stated that they felt uncomfortable wearing the devices, or that their performances felt stifled or negatively impacted by the devices. In casual discussions with audience members after the performances, none of the spectators mentioned anything regarding these small devices being distracting. With the results from the recorded and analyzed data, we can clearly show that the use of the *Sonic Vessels* methodology presents a novel performance experience for the performers and the audience alike. Our findings for these performances guided our approach to the next performance at Bar Transit, which will be discussed later in this chapter.

Post-Performance Discussion and Evaluation

We interviewed the two performers (minus myself) from the Media Studio performances to inquire how they felt performing with the *Sonic Vessels* method. In these post-performance interviews with the performers, Aoi Uyama and Kozue Matsumoto both stated that they felt like the second performance felt more natural and engaging. While this may be in part caused by the fact that it was the second consecutive performance, the validity of this statement was verified through the post-performance data analysis. It was also stated that in the second performance, there were small moments where the adjusting tempos were felt more strongly. One of the performers specifically stated that this feeling was interpreted as more organic than performing without the average BPM data driving

the tempo. This specific moment coincided with the data discussed in number 2 of the previous Findings section. It was also stated by both performers that having this bespoke robotic music instrument performing alongside them without any visible human intervention gave them a new sense of performative inspiration. This could be due to the fact that we are used to seeing humans performing instruments but when it is a seemingly autonomous object playing with us, it can inspire a new sense of collaboration. However, utilizing this kind of novel performance object is central to my method and based on this performance was successful in presenting a sense of presence in something that normally would be inanimate on its own.

When evaluating a live performance work or musical composition, there are many evaluation methods which can be applied. Generally speaking, there is no one right or wrong way to approach this. Much of the current and past evaluation methods for these kinds of performative works are largely qualitative or interpretive, or even based on success metrics such as album sales or ticket sales. With my method, I believe that using a combined qualitative and quantitative approach serve the concept best. There is not a larger importance on data analysis versus open discussion and interpretations from the people who utilize the method or experience the presented live works. Instead, these two methodologies should exist hand-in-hand to provide a grounded and inclusive evaluation approach.

4.2.2 Bar Transit, July 2023

The data recording setup and procedure for this performance was identical to the one in the previous section. However, the main difference is that we were not able to repeat this performance, so the A/B testing approach from before was not applicable. This performance was used to validate in-the-wild the findings from the lab studies on the perception of different musical material and compare the audience reactions to the performances in the Media Studio. We indeed found similar patterns in both recordings: peaks in EDA data towards the end of each piece and the HRV patterns resemble the ones we have seen in the Media Studio dataset. However, the performances were different enough, so we do not expect the results to be identical.

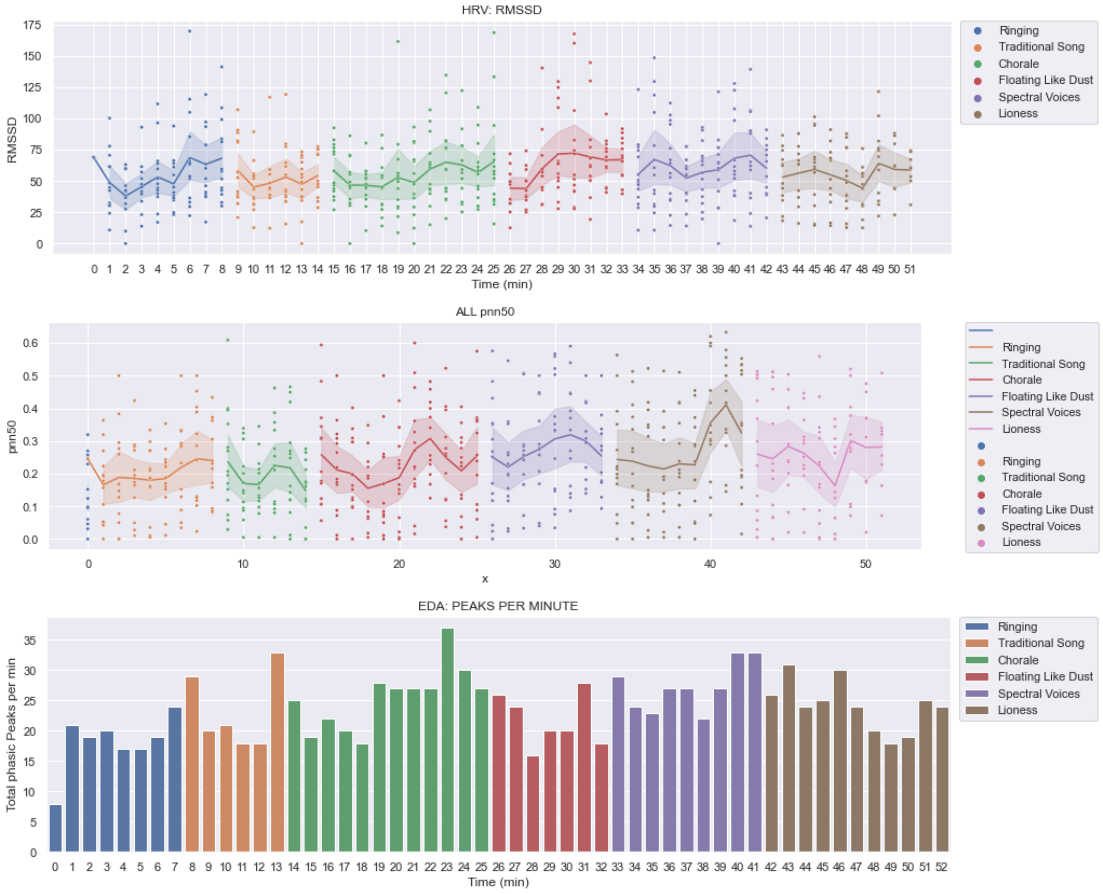

Figure 4.7 Summary data from the third Performance. Top: RMSSD metric of HRV of all subjects, outliers with Z-score over 1.5 are removed. Bottom: number of Phasic EDA peaks per minute for all the subjects.

Findings

With the deployment of this performance, we gathered significant findings in the data analysis which will be discussed. These served to validate the intention we had going into the performance and further validates this *Sonic Vessels* method as a viable and novel methodology. The main points which we deployed for further validation included non-synchronous rhythms, the introduction of vocalizations, and implementation of performer data.

1. At minute 23, during the song "Chorale", there is a noticeable spike in both EDA and pnn50. This coincides with the moment in this song when the performers data began generating non-quantized sounds in the Eurorack synthesizer, whereas earlier in the song the Eurorack synthesizer was being manually controlled.

2. At minute 31, towards the latter part of "Floating Like Dust", the performers data began to be applied into the Eurorack synthesizer. This coincides with a noticeable spike in both EDA and pnn50. Earlier in this song up until this point, the Eurorack synthesizer was strictly controlled by the performer and no data was being applied.

3. In minutes 40-41, at the end of "Spectral Voices", the vocalizations from Aoi Uyama and Juling Li begin to playback and run out of sync, while the performer data takes control of the playback speed and the previous rhythmic aspects began to fall out of sync. This implementation was utilizing our previous findings of significance in vocalizations, non-quantized rhythms, and performer data implementation.

4. In minute 48-49, there is a drop in EDA and pnn50 levels, which corresponds to two things: a reduction in instrumental layers and the de-synchronization of rhythmic content.

Based on these findings, we were able to further validate the hypothesis that utilizing this method of performer presence in live music works gives a novel experience versus performances without. With this Bar Transit performance, all but one of the intended implementations proved to be verifiable within the data

analysis. The one implementation which was not successful was in minute 13 when performer data was applied to the robotic in minutes 43-44 of "Lioness". While there was a very small change in the physiological data, it was not significant enough to include as validation in this performance.

4.2.3 Performer/Composer Interviews

Table 4.1 Interview Feedback from the Composers and Performers

		Composer	Improvisation	Performing	for other Performers	for the Audience
1	Patrik:	Y		X	Y	X
2	Kozue:	Y	Y	Y	Y	X
3	Scott:	Y		Y	Y	X
4	Shoshi:	N		-	X	X
5	Evan:	Y		X	X	Y

As seen in Tab.4.1, five performer/composers were interviewed in order to gain more insights from musicians' perspectives what they would like to see in this kind of method and how we can shape the method to better accommodate a wide range of performance philosophies. These interviews were intended to inspire us to optimize design feedback surveys for a much larger inquiry into how we can shape this method in the future and gain valuable insights into the interests of professional performers and composers.

Of the responses we received, the average age was 38.4 years of age, with 29.8 years of musical training, 22.8 years of performing live, and composing music for 15 years (one responding musician does not compose music). We asked them a series of questions regarding our method for physiological sensing and live performance, and how this method might be applied to composition. These questions revolved around how they might apply this kind of method, what sort of concerns they may have, and how it might change their overall approach to performative expression. Below are some of the highlights from these interviews:

1. In response to whether or not the performers would find a visual indicator of the performers' physiological data, all the composers who prefer performing over recording music (3 of them) in their practice expressed that they are

interested to know other co-performers relaxation/excitement levels through visual indicators. This was seen more as an extension of the performance itself. However, most of the musicians (4 out of 5) showed hesitation to this due to the fact that it might distract them or cause them to focus too much on the audience and not on their performance. Yet the audience feedback during live performance is also not the focus of this work. Only one musician who prefers recording music over performing mentioned she would like to see audience data while feeling no need to see other performers. This also showed different preferences in live performing could lead musicians to be interested in different aspects of applying our system.

2. Regarding the kind of visual cues they would prefer to see, all responses indicated they would prefer a more vague or graphic score as opposed to any kind of traditional notation. This would allow them to create more freely and in line with established improvisational methods.

3. Two of the responses indicated that they are somewhat attentive to the audience during performance while the other three stated that they have little to no focus on the audience. However, all five stated that they are very attentive of the other performers, whether through visual observation or by listening and responding to their musical gestures.

4. All musicians agreed that they were very interested in performing alongside an artifact which would represent physiological data. One response indicated interest in this artifact showing the audience data, while the other four preferred to only have it embody the performer's data.

5. The four composers of the group all indicated that they would be very interested in using this system for composing music. One response indicated uncertainty in using it live but instead would prefer to record data and allow that to create a graphic score to then perform live.

Based on the results of these interviews, it seems that there are a number of possible implementations which can utilize the *Sonic Vessels* method. Regardless of whether it is a composer, performer, or both, there were positive responses to the chance to use this method. One interesting finding to me was that not all

performers would like to understand other performers data, but the one performer not interested in this also was the only one who wished to understand the audience data. This goes to show that a broad range of interests and intentions can benefit from and utilize my method.

Chapter 5
Transient Vessels

This section dives into the second classification of *Sonic Vessels*, which are called "Transient Vessels". These works are born out of a desire to explore how remote and non-linear performances can extend the possibilities of performative reach and expression. Inspired by the early work of *Ephemeral Counterpoint*, which was discussed in Chapter 3, these works defined themselves as related to but in some important ways unique from the Momentary Vessels discussed in Chapter 4. These unique differences can be seen as:

1. Transient Vessels focus on performances which exist outside of a particular location or time.

2. Works which fall into this category are presented in a way which provides physical separation between the audience and the performer.

3. These works incorporate past experiences into the present experiences.

The initial groundwork of this classification of works began from the utilization of old recorded media formats in *Ephemeral Counterpoint*. On a conceptual level, these old mediums were able to not just serve the primary function of documenting sound and audio, but become instruments themselves. The gestural and sonic content of this piece was solely portrayed by these mediums, much like the approaches of musique concrete artists. Despite the mixture of old (late 1980s/early 1990s) material and newly recorded material, all of it coalesced into a singular presentation which was strongly nostalgic and a bit anachronistic, rendering the actual timeline of the sonic creations irrelevant.

In addition, this work allowed me as a performer to present my work in a way that did not require me to stand in front of an audience while performing. For

much of my life as a performer, I have struggled with stage fright and intense unease when performing live. This installation-based presentation alleviated this greatly. This brought me to a realization which is central to the Transient Vessels approach: if the audience is somehow removed from my direct interaction, could this assist me in finding a more peaceful and comfortable performance dynamic? This would soon become a core tenet of this classification of Sonic Vessels.

Slightly opposed to the quantitative data which served to validate elements of the work presented in Chapter 4, the works which I present in this chapter focus largely on the process and thorough exploration of the conceptual, performative, and compositional structures that make up these works. As stated by composer, performer, and theorist David Rosenboom, presenting a unique musical style depends on "the music's strength depends on the degree to which the model is complete, consistent and well- ordered" [120]. This view of the design and implementation of the ideas and concepts which constitute the works core validation and evaluation as a compositional and performative method. I will give detailed insights into the conceptualization and implementation of these works, present the findings which came from the presented performances, and discuss the qualitative questionnaires and feedback from the audiences as supporting material. Although some quantitative data will be discussed in the work titled *Spectral Counterpoint*, this data is meant to serve as supplementary to the design philosophy and exploration of this work.

5.1. *Phantom Undulations*

In a typical live performance, the audience experiences this event in real-time while the performers are present in the venue. Live-streamed performances add the possibility for people to experience these works in a remote setting and have been quickly growing in response to social distancing rules. Furthermore, documentation of live performances has given the opportunity for people to experience performances at any given time. One important aspect which I explore with *Sonic Vessels* is the possibility of extending and challenging the notion of presence in live works. This entails exploring the concept of a performer's presence and the significant influence of time and duration on how a performance is perceived. By

delving into the temporal dimension within the realm of live performances, we might open the door to a novel and adaptable experience in terms of duration. This could potentially enable an experience where the present, the past, and the future all coexist as integral components of the same artistic work.

Phantom Undulations is a multimedia installation that employs real-time physiological data as an input to create a dynamic auditory environment. My remotely-infused data serves as the driving force behind the sounds, musical structures, visuals, and the motion of sound elements, which can be experienced in various performance or gallery settings. Additionally, multiple versions of this exhibit can exist simultaneously in different locations worldwide. One fundamental concept underpinning this work is the exploration of how the uncharted actions and presence of a "performer" are perceived by attendees. These objects can also be duplicated, enabling the simultaneous sharing of this work with people in different places throughout the world.

Primarily, this work seeks to uncover the kinds of connections people can establish with an abstract sonic entity, even in the absence of prior knowledge or a clear view of the performer-object interaction. Attendees will have only the object to engage with, and their understanding of the performer's actions will be limited. Will people become curious about the methods employed by the performer to generate the soundscape and responses? Will the physical separation and absence of a direct visual connection with the performer foster alternative interpretations of the exhibit?

5.1.1 Design

Phantom Undulations is meant to convey my own presence and daily life within a sonic object which is then simultaneously being exhibit in different parts of the world. The design has been conceived in such a manner that each individual object can autonomously maintain its existence while concurrently participating as an integral component within a remote ensemble. The overall vision is that of a string group in which all performers are located in different physical locations. Although their individual artistic creations possess intrinsic appeal and self-contained integrity, they come together to form a composite ensemble. This practice draws significantly from the theoretical principles underpinning early counterpoint com-

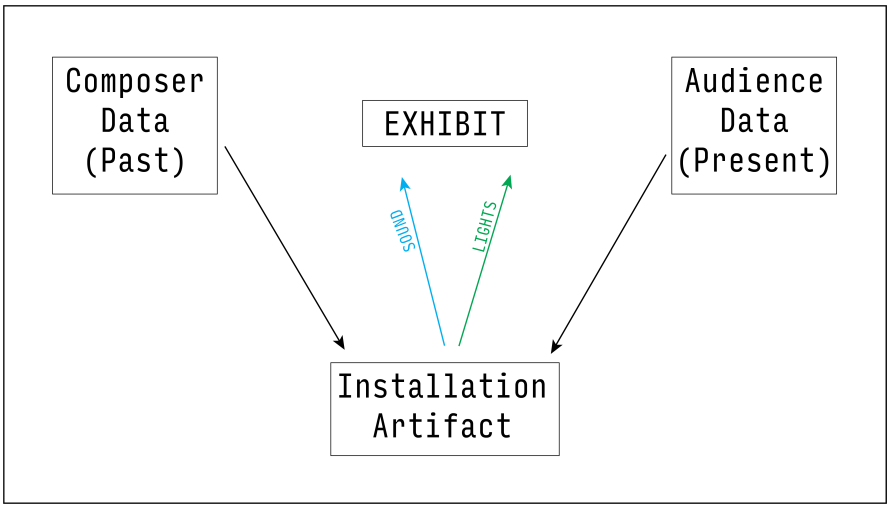

Figure 5.1 Example of Concurrent Remote Objects in *Phantom Undulations*

positions. Within these compositions, each distinctive musical voice is intended to offer independent expression while simultaneously serving as an indispensable part in the realization of the collective musical work. According to music theorist Ernst Kurth, counterpoint is "how two or more lines can unfold simultaneously in the most unrestrained melodic development, not by means of the chords but in spite of them" [121]. This theory is a huge part of this work, and thus I will be presenting the work as such: a geographically separate yet musically inseparable and simultaneous sonic work.

The visual layout of this work is in a constant state of flux, but underlying aesthetic inspirations include underwater plants, iridescent color palettes, and slightly mechanized installation works. My collaborator on the visual design is Hua Ma, a current PhD student within Embodied Media. We collaborated together on a previous work of mine titled *Sonitecture: Module I* which was previously discussed, and the previous visual design slightly informs the current design ideas. I want the visual aesthetic to be complimentary to the meditative musical setting, so it will be subtle.

5.1.2 Iterative Compositional Exploration

The process of determining the tonal and rhythmic structure of this work came together rather quickly. I had already been developing a pseudo-generative Max/MSP patcher which would slowly shift the register of the chosen notes every few minutes. In the original design, the tonal center was G minor and stuck with notes predominately found within the basic triad of G-Bb-D, with the slight chance of the 7th and 9th scale degrees of F and A occurring. Once I began to implement my pre-recorded data into the Max/MSP patcher, I found that the addition of the occasional 7th and 9th scale degrees actually seemed to take away the tonal complexity, in the sense that it started to become a constant minor 9th chord. To alleviate this, I decided to assign the 7th and 9th scale degrees to the audience/participant data. This would give a more clear indication of the role that the audience plays in the overall soundscape while still keeping the sonic variety somewhat broad. All of the pitches which were used had a similar envelope, which used a short attack followed by a long release. All of the sounds were run through the Valhalla Supermassive reverb VST, which had a very long decay and was set at 25% wet/dry level. I initially planned on having the percentage of the wet reverb signal be quite louder, but after hearing it through the small exhibit speakers, I found it to be somewhat muddying. In terms of data application, I ended up going with the first iterative option, which was to have every 8th heartbeat activate a new tone whose pitch was determined by the average variable data stream. The note choice was based on a scale of 0.-1. and the notes were assigned in rising pitches (the first one being G2 and then sequentially going upwards through the sequence of G-Bb-D for my data and G-A-Bb-D-F for the participant data). After experimenting with this for several hours, I attempted two other possibilities. The first was to have the key shift when a certain number of participants use the exhibit. As an example, every 5th audience participant would shift the tonal center up by a 5th. The second alternative was to have the possible pitches restricted to only two possible pitches: G in different registers for my data and D in different registers for the participant data. Although both of these alternative options sounded quite nice, I ultimately felt that the original G minor option provided the most inviting tonal center while also affording enough variety in the experience. I intend on exploring the second alternative of two

pitches only in a future work titled *Ephemeral Counterpoint* which I will discuss in Chapter 6.

5.1.3 Public Exhibition

This work was debuted as a demo in the Augmented Humans 2023 conference which took place in Glasgow, Scotland. The object contained two speakers, a small PC computer, a handful of LED lights, and was connected to the internet via a wifi module. The object was constantly streaming a recording of my physiological data which included EDA, HRV, respiration rate, and average BPM. Although the initial plan was to stream my data in real-time, difficulties in securing a reliable enough stream proved more difficult than initially believed so a pre-recorded stretch of my data was recorded to ensure performance quality. Future implementations of this and similar work will focus more heavily on the real-time streaming of data, which will be discussed later on. These data streams (EDA, HRV, respiration rate, AVG BPM) independently controlled the structure, tonal pitch selection, lighting, and tempo of the soundscape. Participants at the conference were invited to put on sensing wristbands and thereby incorporate their own data into the object, much like my data was. Their data did not include the respiration rate but everything else was made as a copy of my own, save for one big difference: each added participant would be given a slightly different set of possible pitches and patterns. All of the sounds were crafted in the key of A minor and all rhythmic and melodic material was crafted in a way that they could co-exist harmoniously, regardless of their entrance or exit. In a sense, it is an ever-changing and indeterminate form of contrapuntal harmony.

The sounds which occurred were all sine waves and triangle waves generated within Max/MSP, which also served as the main control mechanism for the entire installation. Finally, there were recordings of a noisy air conditioning vent in our lab whose playback speed was attached to moments of synchrony between my data and the data of participants in-person at the conference. To gather the participants' live data, we used the same wristband sensing devices which I used to record my own data. When the levels of the participants' data was inline with my own data, the playback speed would increase or decrease by 50%, alternating back and forth between the two (slowed down by 200% to 150% and

back again). The choice for using the noisy air conditioning vent was a purely aesthetic one: I thought it sounded really appealing and unusual so it was recorded and incorporated.

5.1.4 Installation or Performance?

This work, in my view, falls somewhere between a performance and an installation. On the performance side of things, the participants at the conference are actively putting on these sensing wristbands and creating their own harmonic and rhythmic materials which are then combined with my own. In this sense, they are actively creating their own voices within the larger scope of the musical soundscape. While this is not done in a specific or intentional way, one could argue that their presence is a performative one.

On the other hand, the way in which it was presented is much more in line with an installation. An object was seated on a pedestal and participants could come and go freely. There was no prerequisite for their engagement, only the option to include their presence in the soundscape and visual feedback. Although the side of installation may seem much more stronger than the performative one, the initial intention and certainly the future works of this piece and others will lean much more heavily on the performative end of things. Overall, the initial intention of using my passive data from everyday life as an expressive mode of installation/performance works remains strong. I truly think that using this kind of passive expression as something that will ultimately be experienced as something far more intentional or musical can open up a lot of possibilities in embodied art works.

5.1.5 Discussion

During the conference, we were unfortunately unable to attend in-person and therefore did not get any recordings of the data of the participants. Having this work shown at a conference was a good sign that at least this idea is appealing to people besides ourselves. However, the overall presentation and experience of the people there was overwhelmingly positive. Of the seven people who gave oral feedback of their experience, all but one of them stated that they felt some kind

of unusual or novel feeling of presence when interacting with the object. The fact that they had no visual or written indication of the state of the performer whose presence was imbued into this object led them to ponder more openly about this. One of the main areas which showed a need for improvement was with the degree of similarity in sonification between the people being presented. For instance, all of the on-site participants were sonified through similar synth sounds, while the performer was sonified through a slightly different, yet not different enough sound. This lack of sonic diversity led to a feeling of everything blending together, creating a rather unified sound. Furthermore, the lack of visuals, while leading to an interesting sense of wonder in the participants, also led to more questions regarding the actual intention of this piece. Overall, the lack of diverse sounds proved to be the biggest weakness, while the lack of visuals of the pre-recorded presence source proved to be the strongest part of the work.

One of the main things which I intend on exploring more with this piece, as I said previously, is the performative side of it. When my data is being sent directly to an external sonic object which I may not be able to see or hear myself, it separates my physical presence from the equation and in fact separates my performative intentions from it as well. If my intentions as a performer are taken away, how will the collaboration of other participants or musicians be transformed? This is a topic which required further study and was more thoroughly explored in the next project, *Spectral Counterpoint*.

5.2. *Spectral Counterpoint*

Spectral Counterpoint is a project which takes many of the aspects of my thesis research and incorporates them into a cohesive and succinct performance practice. This work aims to explore and challenge the performative role of an in-person performer vs the remote presence and intervention of other performers/participants. In many ways, this performance piece is a culmination of my thesis topics. In this work, a performer (in this case, myself) presents a live performance using an extensive Eurorack system along with numerous old or "obsolete" technologies, including 1/4" tape machines, cassette tapes, mini discs, and Hi8 videos. While the performer is alone on the stage, remote participants are incorporating their

real-time physiological data as a performative presence. This remote participation is done via physiological sensing wristbands which send their data to a dedicated IP address. This IP address will provide access for a processing computer in another location to gather the data and then relay it to the performance computer. In essence, the performer is not simply creating music on their own but mixing and conducting the remote presence of other people. Another core aspect of *Spectral Counterpoint* is a more comprehensive exploration of what I describe as "ephemeral temperament". This early in development concept is to base the musical temperament, or tuning system, of a performative work on the real-time physiological data that is being created by the performers and/or audience. By connecting the core tuning system of the work to the presence of the people involved, these works can fluctuate and take on their own unique aspects with every performance. To summarize, this work will present:

1. Remote participants controlling aspects of the musical work and performance via their sensing data.
2. The implementation of obsolete technologies in new and novel ways.
3. The performer allowing for a reduced sense of control and agency, or shared agency.
4. A graphic score which is generated in real-time.
5. The use of "ephemeral temperament" to create a bespoke tuning system for every performance.
6. The concept of "phantom presence", i.e. the recorded performance data existing in subsequent performances alongside the live data.

As can be seen, this performance work explores all of the aspects of my research and presents a fully realized version of the *Sonic Vessels* method for liveness in performative works.

5.2.1 Design

The performance and experience design of this work began with the results of the previously presented *Phantom Undulations*. As was mentioned in the previous section on this work, I found something extremely affecting about giving a performance in which my presence was a core aspect while being able to have a separation between myself and the audience. In the case of *Phantom Undulations*, it took on a much more installation experience as opposed to a more traditional performance. However, this aspect of partial disconnection from the audience is where my thoughts began with *Spectral Counterpoint*.

The initial brainstorming focused on how this partial disconnection could be achieved in a more traditional performance paradigm. It was important for me to still present my own presence and the presence of the audience in some tangible or at least pseudo-tangible way. My first thought was to perform in the same room with some kind of wall separating us. While this seemed somewhat interesting, I began to wonder how off-putting this may seem. If the audience knows that I am behind this wall, then perhaps it would take on a more disingenuous or cold feeling for them. After pondering on this for some time, I came up with the idea of having the sonic presentation be given remotely, which would ensure that the actual design of the work afforded a more genuine feeling for myself and the audience.

The remote physiological data/presence indicator was decided to be done through a dedicated IP address which would be handled by the sensing software laptop. The participants would wear the physiological sensing wristbands and this data would connect to that IP address via custom built software by George. This software enabled the data to arrive to his software processing machine, located in Hiyoshi, with minimal lag between the two. Once this data was processed in real-time in Hiyoshi, it was then sent to my performance laptop in Odaiba, Japan. Over the course of two performances, this data was utilized and recorded, effectively giving me a cumulative set of experiences.

In designing the experience, my strong wish was to create something that was non-linear and remote. To achieve a non-linear presentation, two performances were given. The first performance was more of a trial run to make sure the software functioned correctly and was reliable enough to use in a live performance.

Due to quite some technical issues resulting mainly from connectivity issues in London, the performance was a few hours late. Ultimately, we were able to record the experience of several audience members, which would then become a core part of the next performance. The recorded experiences of the previous audience members co-existed with the next audience, serving as a sort of memory shared between the two. As stated by Lee Gamble, "memory is a kind of simulation, and voices without a physical source are illusive and psychedelic things" [122]. In essence, these memories are never fully given a physical body, but instead join together in comprising the collective memory and history of this on-going work. *Spectral Counterpoint* is a constantly ebbing and flowing performance work. The recorded presence and experience of each audience is then utilized in the next performances, wherein past and present experiences are coalesced into one. As described by David Rosenboom, "the concept and perception of a *now* - a present - is a *resonance*, a finely-structured loop linking a synthesized past with a projected future" [123]. Building on the previous experiences of these works with the knowledge that these experiences, these moments of *resonance*, will in turn become both synthesized past and projected futures, allows for a flexible non-linear expression to exist. They are not merely documented performances or recorded memories, but instead structural building blocks of this experiential loop which Rosenboom describes. If this kind of subtle and passive experience sharing can be done consistently, then the connection between audiences can be bridged and gathered into a collective one. To borrow once again from David Rosenboom, a *collective resonance* where past, present, and future all co-exist.

Technical Setup

The technical setup for this performance consisted of:

1. A performance laptop running Max/MSP for processing the incoming physiological data.
2. My entire Eurorack system.
3. Several tape machines, including a Tascam Portastudio 4-track cassette recorder, two Sony 1/4" open reel recorders, and one Panasonic VHS machine.

4. Four film cameras, including Hi8, MiniDV, Betamax, and VHS camcorders.

All of this equipment was set up in the Cyber Living Lab at Odaiba, Japan. This live performance was streamed (only the audio) through Mixlr, a program for streaming live audio. All of the participants were listening to this performance on speakers, while they were all wearing the physiological sensing wristbands which were connected to a laptop in the room with them. This laptop was running the sensing software which connected their data to the static IP address in Hiyoshi, Japan. The remote locations were: London and Hiyoshi for the first performance, and Los Angeles and Hiyoshi for the second one (along with the phantom experience of the Friday audiences). As you can see in Fig.5.2, the green arrows indicate the flow of audio while the red arrows indicate the flow of presence detection.

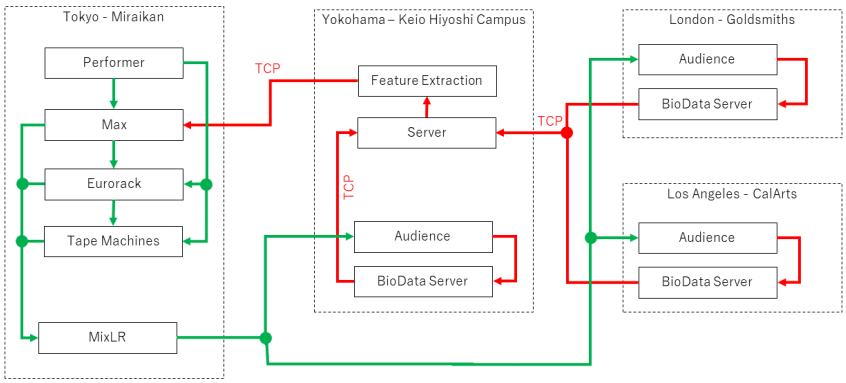

Figure 5.2 Flow of Presence in *Spectral Counterpoint*

5.2.2 Iterative Compositional Exploration

This performance was conducted and developed through an intensive iterative process. This began with utilizing a native Windows application developed by George Chernyshov which replays the data from a previous performance, which allowed me to become more familiar with the flow of data that could reasonably be seen during the live performance. This executable offered four variants of data

groups, each with their own average BPM and average varying data stream. These data streams followed the previously established protocol for data (float numbers for the average BPM of each group and a float between 0.-1. for the varying data stream). Since I already had this in my possession, the trial and error iterative process was able to begin at once.

The first step was to establish a set of pitches which would be available for me in this setup. As opposed to the available pitches with *Innermost Echoes* which was centered on the capabilities of the robotic koto, and *Phantom Undulations* which was generated solely within Max/MSP, this performance blended three sonic groupings:

1. Max/MSP generated sine waves run through the Valhalla Supermassive reverb plug-in.

2. My extensive Eurorack system.

3. Several old tape machines (VHS, cassette, 1/4").

The iterative process began with the first section, which was solely performed within Max/MSP. I began by exploring what kinds of gestures would be realistically possible through the pre-recorded physiological data. To start, I began with routing the average BPM of each group (what would eventually be the first performance's Hiyoshi audience as Group 1 and the Los Angeles audience from the second performance) to triggers in a bass drum sound and a click sound respectively. The direct routing felt far too active and cluttered, so I designed a multiplier/divider for the incoming BPM, which allowed me to take ratios of these triggers. This worked much nicer in terms of rhythmic density and activity, with the beginning of the performance set to a divided ratio of 5.5 in the kick and 6.5 in the click. These ratios were the ones which I found to be the most pleasing rhythmically, at least in terms of a starting point. At this slow of a tempo, and the fact that they are not synchronized, led it to create a more sparse atmosphere than a proper beat.

The next step was to establish a tonal center, which was done through the iterative process I discussed earlier. Once the tonality of A minor was decided upon, I approached the ADSR (attack/decay/sustain/release) of the two sine

waves in the same way as the kick and click sounds. Each were being fed the average BPM of the two groups and then utilized a multiplier/divider. Instead of linking up these clocks to the previous rhythmic ones, I decided upon a simpler ratio of divided by 4 and divided by 5, which allowed them to be more focused in relation to the rhythmic sounds. The overall resulting sonic aesthetic vaguely referenced gagaku music, in which the rhythms and tempos are quite fluid and determined in the moment as opposed to being set to a metronome or click track.

Once these foundational elements were established, the process of assigning possible notes for the sine waves and playback speeds for the percussive sounds came next. In Max/MSP, the average variable data of each group was assigned to one wave oscillator each. For these, a range of 0.-1. was used. Within this range, five equal sections were divided up as follows: 0.0-0.2/0.2-0.4/0.4-0.6/0.6-0.8/0.8-1. These five groupings were then used to determine which portion of a 15 note midi sequence would be selected. Each sine wave generator was given notes within A minor, and each group has the same bottom three bass tones (21/A0, 27/E1, 33/A1). The remaining 12 pitches were assigned to span across three octaves (A3-A5), and included a predominately Aminor9 tonality, which is comprised of the A minor triad (A-C-E) and the addition of the 7th tone (G) and the 9th tone (B). Additionally, Group 1 also had one instance of the 6th tone (F) to allow occasional tonal coloring.

After these musical parameters were established to the point where I felt they were ready, I tested them out as-is with the Eurorack system. In essence, the same exact MIDI signals wre used. Only this time, the signals were sent to a MIDI to CV converter by Expert Sleepers, which allowed these signals to make their way into the Eurorack system. Since the oscillators I used were calibrated specifically to the FH-2 MIDI to CV converter, the same tonalities were somewhat achieved. One major change I made was to shift one of the oscillators (Group 2) to a triangle wave to add more timbral variety compared to the first movement. Similar rhythmic sounds were used on the Eurorack system, although the bass drum sound has more low end resonance which added to the heightened intensity of the second movement.

5.2.3 Public Performances

The first performance of *Spectral Counterpoint* took place at the Cyber Living Lab in Odaiba, Japan on November 10th. In this first performance, the live-streamed presence data of participants in London and Hiyoshi were utilized as performative and expressive elements. The performance consisted of myself on Eurorack synthesizers, tape machines, and laptop, while the remote participants' data triggered and manipulated many parameters of my setup. Furthermore, I gave myself a visual score which showed the incoming data as a slider for each incoming data type, with the blue coloring indicating a low level and red indicating a high level. Much like a conductor's score, I saw these streams and direct them to the desired locations and parameters.

The second, and I would say most full and official, performance took place on November 13th. This performance presented the core concept of *Spectral Counterpoint*, which is to utilize a non-linear approach to performance in which prior experiences co-exist with current experiences. This non-linear approach allows for people across different times and places connect in some way to the performance and to each other as a collective experience. In this second performance, an audience at CalArts in Los Angeles and an audience at Media Studio in Hiyoshi were joined by the previous Hiyoshi audience, and all of their presence indications were utilized in shaping the performance. Instead of using all of the data, I instead used the previous audience data and the Los Angeles data only. The reason for omitting the Hiyoshi audience was to see if they felt any differently from each other when they believed their data was used.

5.2.4 Audience vs Performer Data

This project presents an interesting question regarding the role of audience members vs performers, in that the remote "participants" as they are referred to could easily be seen as either/or. While they are not actively engaging in the work in a performative sense, their experience while listening to the work in real-time is having a direct effect on the performance itself. This echoes some of the work I contributed to previous works such as *Boiling Mind* or *Frisson Waves*. In these works, the audience's data was controlling certain aspects of the music I created.

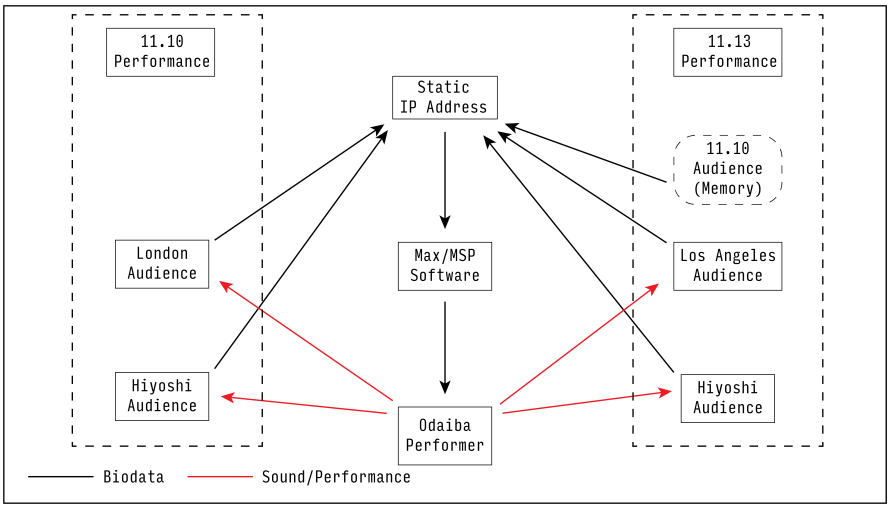

Figure 5.3 Diagram of Remote Participants and Live Performer in *Spectral Counterpoint*

When composing for these performances, I had this integration in mind and allowed for a certain degree of flexibility in the composition itself, ensuring that enough room was given for the audience's engagement to be able to have an effect while still ensuring that the performance itself would still be sonically and performatively enjoyable. Some of this carries over into this performance work, but I am putting a much greater emphasis on the live performance itself. Instead of allowing for the direct audience to have a controlling input on the sounds or performance, I have selected specific people who will engage in the work not only as audience members but also as performers in a certain sense of the word. They are not sitting in the audience, but instead will be given only a (sonic) glimpse into the work being carried out. This can pose a few crucial questions. For starters, are they still considered to be audience members if they are given this specific role in the creation of the work? Does their remote location affect their role as audience and/or performer?

As can be seen in Fig.5.1, the performer is the only one who is giving direct communication to the other two people/groups, while the remote participants are the only ones who are giving both direct and indirect communication.

To answer these questions fully, I will need to present the works several times. However, I do not see these questions as paramount to understanding prior to

Table 5.1 Direct vs Indirect Communication in *Spectral Counterpoint*

Direct	Indirect
Performer to Audience	Audience to Performer
Remote Participant to Performer	Remote Participant to Performer
Performer to Remote Participant	

the works being presented. In some sense, these performances are as much improvisational or indeterminate as they are structured. Part of the drive for these performances is to explore these questions as they occur together with the live audience, the remote participants, and myself. The main reason that I decided to shift away from utilizing strictly audience data was to explore more of the performative side of physiological sensing. By focusing on the performers, then we can present something new for us which should in turn be new for the audience. When we utilize strictly the audience in live performance, there still seems to be some kind of divide: the audience has physiological control over the works, and as performers, we are beholden to this incoming data (in some sense). Although I don't have the answers to whether or not the remote participants are in fact audience members or performers, it is this unknown that I find most appealing. We can discover and explore this overarching question together. The constant changing and morphing nature of this work is one of the most appealing aspects for me. With new forms of media performance, this constant state of flux can be greatly achieved. As stated by Lev Manovich, "a new media object is not something fixed once and for all, but something that can exist in different, potentially infinite versions" [88]. Through the process of basing much of this performance work on a combination of real-time and past experiences, *Spectral Counterpoint* will never fully be realized to any end. It will simply evolve along with the memories and experiences of everyone who has engaged with it, forming a transitory counterpoint between the past, the present, and the future.

5.2.5 Discussion

With this performance, we were able to record the biodata of the remote participants for further study and analysis. This was done through both qualitative

questionnaires, open interviews following the second performance, and quantitative data analysis of the remote participants. In this section, I will discuss the findings of these methods along with my own thoughts as the composer and primary performer.

Questionnaires

For this work, we gave qualitative questionnaires to the remote participants to get their insights into their role in this work and their thoughts on perceived presence and affect. 14 participants were asked to fill out these questionnaires along with an open discussion following the performance. These questions were a mixture of open-ended questions and questions regarding the sense of presence and affect, rated on a 7-point Likert scale. There were a few interesting things which we were able to extract from these questionnaires.

1. In the second performance, the Los Angeles participants rated the level of sensing a presence at 5.75/7, compared to 3.06/7 from the Hiyoshi participants. The interesting point here is that the presence of the Los Angeles participants was being used, while the Hiyoshi participants did not have their presence utilized.

2. For all of the participants, there was an inverse relationship between feeling a sense of emotional reflection and a feeling of engagement. In other words, when they felt a strong sense of emotional reflection in the music, they felt a low sense of engagement, and vice versa. This was not something that we anticipated when we designed the questionnaires, but it poses an interesting idea regarding emotional connection and engagement.

While these questionnaires were not exhaustive, they offered a valuable understanding of how this performance work operates as a remote presence-sharing experience. One of the most meaningful insights would be that, despite great distances separating the performers and the participants, there still seemed to be some sort of enhanced experience for those who were experiencing their own presence being sonified versus those who were not being actively implemented.

Quantitative Data Analysis

For all of the remote participants, we were able to record their biodata which was then analyzed to see what kinds of connections and insights we could gather from it. Although we only had 14 participants in total, this still provided a valuable insight which could support the qualitative findings we found. One of the biggest insights we found can be seen in Fig.5.4. In this graph, the heartrate variability metrics of the participants from Los Angeles is shown. In these graphs, you will see that the variability and overall levels do two things of interest:

1. As the entire performance progresses, the levels and variability rise.
2. Within each 10-minute movement, you will see slight increases in variability towards the second half of the movement.

Figure 5.4 Excerpt of recorded biodata from participants in *Spectral Counterpoint*

From this supplementary data analysis, it seems to show that as the mediums being used move more towards analog, the variability increases. Furthermore, the second 5 minutes of each 10 minute movement were ones in which I, and

the primary performer, would intervene. In the first 5 minutes, I simply allowed the remote participant presence control everything. This would seem to suggest that (1) the use of perceptively analog or "old" technologies can cause a stronger reaction, and (2) direct performative intervention causes a slightly more engaging performance versus a fully data-dependent work. This quantitative analysis is not meant to be exhaustive or final, but is simply presented as supporting data to go along with the qualitative questionnaires.

Performance Notes

As the primary "performer" of this work, I found several things which stood out to me that seemed to be unique to this particular setup and implementation. First of all, the fact that I could not see nor could I interact directly with the remote participants was a rather surreal experience. Admittedly, I have always struggled with stage fright and a general sense of unease when performing. I trained myself to try as best as I can to block out the audience to prevent these nerves from getting the best of me. Going into this performance, I felt as though this kind of nervousness would be greatly reduced due to the lack of visual acknowledgement of the remote participants. This turned out to be the case, but it was stronger than I had anticipated. Rather than having simply an alleviated sense of nervousness, I rather found myself wishing to be able to more directly communicate with them in some way. This is mainly due to the fact that I did not see them as just audience members, but rather as some kind of collaborators or even performers. Even though they were not actively intervening in the performance, their presence was a large part of the performative control. This is one of the strongest performative aspects of this work. To be able to situate audience members as performers themselves without having any sort of physical or intentional intervention allows for a more fluid and presence-reliant experience.

Another aspect in the performance which I found to be quite successful was the integration of physical mediums, mainly with the analog synthesizers and especially the tape machines in the final movement. Actively and intentionally using these recording mediums in the final movement felt extremely liberating and challenging all at once. Since these tape machines were limited to capturing previous sounds from the first two movements, it really leaned into the concept of

memory of past events as performative material. Once these sounds from the first two movements were captured onto the tape machines, this was the predominant restriction I had. This allowed me to more actively utilize the smaller nuances of the medium itself, through gestures like playback speed, playback direction, and some slight filtering through an analog reverb tank. Ultimately, this showed me new ways of utilizing recording mediums as performative tools which will carry over into my future works.

All of this said, there was one main thing that I found to be rather underwhelming in this performance work. The first movement was focused on generating sounds within Max/MSP. The downfall of this section was mostly due to the fact that I did not design a flexible or varied enough of a patcher to use. In rehearsals for this performance, it felt much more interesting but in the performance itself, the combination of lack of timbral variety in the sounds and the at times unexpected incoming presence data led to a mostly uneventful and lackluster section. This falls solely on my shoulders as the designer of this Max/MSP patcher and has given me crucial insights into how I need to broaden the sonic possibilities of internally-generated Max/MSP sounds. This lack of timbral variety is likely what led to a somewhat dull response from the audience in both the questionnaires and the small supplementary biodata we collected.

Chapter 6
Discussion

6.1. Performative and Compositional Approach

In this section, I will discuss some of the more composition and performance-specific aspects which were found within the development of this method and how these findings can serve as a more theoretical and qualitative backing. Much of this discussion is focused on the conceptual framework as it was applied and the findings which resulted in their implementation and development.

6.1.1 Live Data and Performative Choice

In typical performance settings, there can be a number of ways in which the performative choices made by the musicians are presented. Sometimes this is done by a strict score in which the performer has choices in how to interpret varying degrees of certain intention in the written material. Other times, the score is left quite open to interpretation, as is the case in many jazz and improvisation-heavy musics. Other times, there is a middle ground, as was seen in much of the contemporary classical works by composers such as John Cage or Morton Feldman. In the *Sonic Vessels* method, the goal is to present an enhanced range of interpretive and performative choice through the integration of dynamic physiological data. When this dynamic and at times unpredictable data is presented as a core element of the performative possibilities, the range of expressions is greatly enhanced. As is seen in Table 6.1, there are certain options which are afforded in this method that may not be regularly seen in other performance paradigms.

While I will not claim to be the only composer or performer to have ever touched these kinds of situations, this method allows for the easy integration and novel exploration of a dynamic performance practice which is unique in how it is inte-

Table 6.1 Performative Choice in *Sonic Vessels*

Approach	Traditional Performance	*Sonic Vessels* Performance
Performer to Performer	✓	✓
Performer to Audience	✓	✓
Performer to Score	✓	✓
Performer to Object	X	✓
Audience to Object	X	✓
Score to Performer	X	✓
Object to Performer	X	✓
Object to Audience	X	✓
Audience to Score	X	✓

grated and deployed. It is equal parts indeterminate, comprehensive, and fluid. Every performance will inherently be different in some way as long as this live data is being interpreted on the stage or in the studio. This will apply as much in a real-time performance as it will in the recurring phantom performances as were discussed and presented with *Phantom Undulations* and *Spectral Counterpoint*. Not only will the real-time live performance be rooted in a dynamic structure, but subsequent "phantom" performances will also allow for new interpretations to co-exist within the previous "liveness", producing a sort of "recurring liveness".

The use of a visual score or guide is also a method in which the unique nature of every performance can come to be. When the performers are seeing a visual guide to how the data is being detected in real-time, combined with instructions given beforehand on how to interpret this data (with certain degrees of freedom determined by the composer and performers in advance), a further layer of dynamic performance is given. This is different than a generative score in the traditional sense. The score is not being generated simply based on an algorithm or pre-defined set of rules per se. The material in which the performers will be guided is mostly or wholly dependent on the biofeedback being given by these same performers. While algorithms do in fact exist within this system, it is the liveness and real-time experience of the performer which guides and shapes the visual feedback, which is then interpreted by the performer, which is then put out

into the world, creating an ever-changing and undulating feedback loop.

6.1.2 Compositional Concerns

Composing for a dynamic system can present certain difficulties which must be addressed and taken into account in order to ensure that a smooth process is allowed and the compositional intentions are met satisfactorily. First of all, it is rather important to set up certain restraints or limits to what this incoming data can do in actuality. For instance, if the EDA peaks are typically coming in at around 0.8 as a float, it is advised to set a threshold at or around this, preventing any unwanted spikes that would exceed this number. In Max/MSP, this is done by using the ZMAP object. This object can scale incoming data without allowing it to exceed the upper or lower limits. Another similar object within Max/MSP is the scale object but I strongly advise to use the ZMAP object instead. This is due to one main difference: the Scale object will allow numbers to exceed the upper and lower limits, whereas the ZMAP object does not allow for this to happen. The ZMAP object asks in a sense as a brick wall limiter, never allowing numbers outside of a given range to occur in the output. This comes with one small (potential) drawback, in that the ZMAP object cannot invert the numbers. The Scale object, on the other hand, can do this. My recommendation is to use the Scale object first and then use the ZMAP object afterwards if any inversion is needed.

While the preceding paragraph gives one example of how to manage these variables in a compositional manner, this ultimately comes down to the restrictions and framework/boundaries you set for the work itself. These boundaries within which the piece can freely exist is a transformative process. Careful consideration should be done to determine what sorts of boundaries you wish to set so that the piece can exist in a flexible way while also ensuring that the chances of "undesired" sonic events can occur. This is not so different from most compositional approaches, but when the composition is based on something dynamic like presence, it is important to create this kind of framework or scaffolding that can provide a firm structure to something that is inherently flowing.

Another compositional concern that should be addressed is the use of incoming biofeedack data as a means of manipulating the structural elements of a com-

posed work (form, cadences, etc). While this can be done rather easily as was discussed in *Innermost Echoes* and *Spectral Counterpoint*, there is a lot of give and take involved in developed the works to fit into this fluid structural approach. Certain musical elements such as harmonic rhythm, melodic counterpoint, and orchestration can become quite messy or unwieldy if not approached with care. My recommendations are to focus not on placing traditional musical structures within this method but instead to embrace the fluid nature of the method prior to creating the compositional language. For instance, in many of the works which have been developed for the *Sonic Vessels* method rely on somewhat simple and rarely changing tonal centers. This was the case in *Innermost Echoes* (predominately staying within one key or strictly atonal), *Phantom Undulations* (wholly in one key and retaining a very slow harmonic rhythm), and *Spectral Counterpoint* (shifting between atonal and strict tonal centers). When placing these sonic works within structures which do not frequently shift between key signatures or massively different orchestrational situations, much of the concerns of clashing notes or rhythms are alleviated.

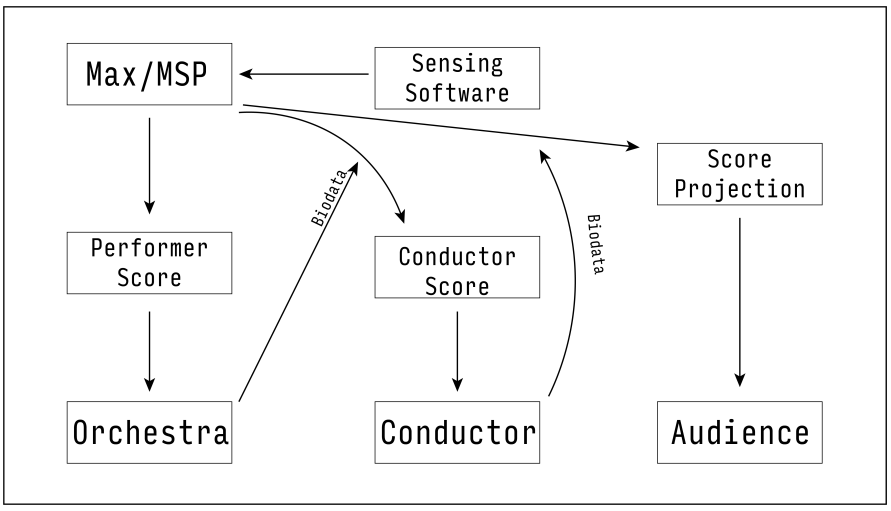

Figure 6.1 Biodata in Live Scores

6.1.3 Interpretation vs Inspiration

Interpretation and inspiration are two hallmarks of live music performance but in many contexts these two can differ from one another in some important ways. For instance, interpreting a written score involves the use of one's own experiences as a performer (and possibly composer) to realize the intention of the composer. While performing with other musicians, the same score could also present the opportunity for the same performer to sonify their inspiration from other performers. This could be the result of a saxophone player presenting an exciting line which then inspires the drummer to increase his/her/their intensity, which could then inspire the keyboardist to shift the key dramatically. There are many, many different ways in which this could take shape. Essentially, these two concepts are not completely separated from each other, but instead are quite co-existing within live performance. I hesitate to place too much emphasis on distinguishing the two from each other, but for the sake of clarity, I will present how these two different concepts could differ from each other and how they could be one in the same within the *Sonic Vessels* method.

1. The data coming from a saxophone player causes a sonic object to shift it's intensity and note choice into a more atonal pattern, which then **inspires** the saxophone player to go along with this and shift their tonality and intensity as well. The sonic object then **interprets** the possible data change and adjust accordingly.

2. A saxophone player **interprets** the movement of the visual score as being quite intense, so they adjust their playing to create a more aggressive sound, which then **inspires** the drummer to increase their intensity as well, causing the sonic object to **interpret** their data as being more mellow and limited, thereby creating a juxtaposition of intensity and relaxation within the same work.

As you can see, while there are a seemingly infinite amount of configurations within this, I have presented two quite different situations which could musically be quite similar, depending on the inspiration/interpretation angle. It is maybe not possible to completely separate the two, and I'm not sure that they need to

be separated in the first place. These are somewhat subjective words given to similar yet distinct aesthetic responses, so an open interpretation, for lack of a better term, is best when applying this philosophy.

Communication and interpretation are important aspects of music and live performance [124]. The ability of music to communicate various emotions and intentions is something that gives it a very conversational aspect. It has also been suggested that one of the composer's roles is to present intentions and meanings which are then later interpreted by the listener [125]. It would makes then to suggest that the role of the composer and performer (interpreter of the given works) can take on a suggestive position in this framework wherein they are presenting a situation in which the audience can draw their own conclusions. But what happens when some of this agency of material presentation is taken away from the performing individuals and instead tied directly to their passive existence within the performative structure? This method I have developed aims to provide this externalization of biofeedback and presence as a means for exploring a more "outsider" perspective on one's own existence: the presence and physiological data of the performer can present a new sense of agency with the performative hierarchy, thereby allowing for novel communication and interpretation within the performing invidious themselves. In other words, these communicative and interpretive structures are not pre-determined as they may normally be, but are distinguished by the *liveness* of the very people engaging in the creation of the work. The visual and sonic feedback which is fueling the bespoke elements of the *Sonic Vessels* work (robotic instrument, Max/MSP generated sonic content, etc) will take the lead on how the communication between performer and their own biofeedback plays out and therefore influence the interpretation of said material by the performers. Although much of this begins to take on a somewhat feedback-based approach, the role of interpreter vs tangentially affective participant begins to blur and questions regarding agency, intention, and inter-personal dynamics begin to arise. I do not suggest that there is one concrete explanation or answer to this situation, but rather suggest that this setting is one in which the performers, composers, objects, and audience members can freely explore.

Table 6.2 Comparison of Remote and In-Person Performances.

Remote Performance	**In-Person Performance**
Can reach any audience with a connection.	Reaches the physically present audience.
Has to account for connectivity issues.	No connectivity issues.
Can incorporate biofeedback.	Can incorporate biofeedback.
Can present *liveness*.	Can present *liveness*.
Can incorporate multiple performers easily.	Can incorporate multiple performers easily.
Is easily documented.	Is easily documented.
Relies on an online audience.	Can exist without an online audience.
Challenge to present the feeling of the space.	Easily presents the physical space.
Somewhat real-time, with caveats.	Is occurring in real-time by default.

6.1.4 Remote Possibilities

As discussed in the previous project *Phantom Undulations* and the more recent *Spectral Counterpoint*, this method of sonic presence indication and interpretation can easily be integrated into remote performance and installation works. The differences between a remote implementation and in-person implementation are not vast but focus on a few main differences. First, on a more practical concern, in-person performances do not need to rely on connectivity issues while remote performances do. Next, remote performances rely on online audiences and have more difficulty in presenting the feeling or "vibe" of the performance space. On the other hand, remote performances can reach any audience with a connection. While more of the differences may seem to favor in-person performances, I would posit that the main advantage to remote performance situations rests on the aesthetic or philosophical merits: when we remove the comfort of in-person performance dynamics, we are then forced to not only reckon with this but to adapt to it and utilize it as much as possible. Simply speaking, the new possibilities in performance dialogues when presenting these kinds of remote works are much more broad and novel than the more conventional approach. However, that is not to say that remote possibilities are inherently better per se, just that there are new avenues of expression that are introduced when you separate time and space from the performance.

6.1.5 Passive Audience Engagement

When looking at how an audience engages with a performance work, there are many different approaches and philosophies which can be taken into account. Although there is no wrong or right way to do this, for the sake of cohesion and clarity, I have chosen to focus my work on the experience of the performer. This was done for one simple fact: I believe that if the performers are given a new setting in which to produce their craft, the resulting works will have a new affect on the audiences who are experiencing them. It does not seem like too bold of a claim to say that if performers are placed into a new and uncomfortable (not in a negative sense) situation, their output will differ from a more traditional setting. Based on the publications we have made throughout this research, the resulting experiences are mostly positive and novel. That leads to an important question: What now is the role of the audience?

I would say that the role of the audience is somewhat similar to what it was before, with a few caveats. First of all, while the biofeedback of the performers is being used to change or effect the performance structures, harmonies, etc., this intervention is not generally presented in a way which is clearly understandable for the audience. This was done intentionally. The focus of this method is not to directly notify the audience of how the data looks or reads, but instead to allow the audience to experience the performance as they normally would. Of course, the audience can know that biofeedback is being used. It is just not something that needs to be explicit within this method. This can be altered or changed by other practitioners if they feel inclined to do so. Next, we usually will place physiological sensing devices on the audience for the explicit purpose of post-performance analysis. Without having this information, it is much more difficult to ascertain how this method is being experienced differently than a traditional performance setup. While the audience feedback is not being directly utilized in the performance most of the time, the simple act of wearing these devices could in itself change how the audience perceives the performance. This could be seen as some form of a placebo effect, where the audience makes connections which are not actually there. I am not wholly opposed to this happening with the audience, but it is not a direct intention of the process. We simply want to have their data for analysis after the fact. Finally, the performer/audience dynamic is

something that is inescapable in live performance in which there is an audience. This dynamic changes based on individual performers, audience members, styles, venues, and many other variables. However, when the audience is aware of and witnessing a physiological intervention within the live music, their role could be seen as becoming more passive than normal. Where this falls in terms of audience interaction is not something that can be clearly defined at this point. I would just say this: despite not having a direct effect on the incoming physiological data, their presence is still a passive influence and is something that will be more thoroughly researched in the future.

6.2. Limitations

Throughout the presented research, many different methods and experiments were explored to structure the *Sonic Vessels* method. While much of the work was successful, there were still some limitations and failures along the way. In terms of failures, I do not mean to present them as necessarily negative experiences. On the contrary, these failures provided invaluable information and inspiration on how to proceed with the work. Although I believe that I have offered an extensive review and analysis of the *Sonic Vessels* system and the current possibilities of using this method, there are certain limitations to the current research which I will discuss below. I will also address the ways in which I plan on addressing these limitations, how they can be resolved, and how they will impact my future works.

6.2.1 Technological Limitations

The technical aspects of my work have generally been successful for my research but there are several limitations to the current method and technologies which I have used.

MIDI VS OSC

Much of this method utilizes a mixture of MIDI and OSC protocol to communicate the physiological data, the musical gestures tied to this data, and the manipulation of sounds and visuals in real-time. This approach has provided a broad range

of expressive and performative capabilities but some issues have arisen in this process. First, there are inherent limitations within each protocol which have come up. With the utilization of MIDI control for the bespoke robotic koto, we chose MIDI as the means of communication. This was done for two reasons:

1. Using MIDI for the robotic koto kept it separate from the existing OSC use within the Max/MSP patcher for organization purposes.

2. We already possessed a MIDI adapter and the necessary hardware to seamlessly integrate it into the main board for the koto.

As you can see, this was decided based on a mixture of practical and expressive reasons. The main issue with using MIDI actually came about based on the software being used, predominately Max/MSP and Ableton Live. With Ableton Live, the expectation was that we could simply plug the koto board into Ableton Live and address it via MIDI seamlessly. However, this did not work as we expected. The software recognized the MIDI device but Ableton Live sends out MIDI messages in a format which was not recognized by the custom software which was written for the board. This issue could have been solved early in the development process, but unfortunately we began the software development prior to our attempts to integrate Ableton Live. This is not a specific fault of Ableton Live, rather an unexpected issue which came about on our end. In future development, we will adapt the software on our end to accommodate other methods of MIDI integration and messaging.

Another limitation which we came across was that of the limited range of expressions within MIDI vs OSC. As before, we do not see this as an inherent limitation within MIDI itself but instead a limitation with my own practice and approach. MIDI has many features such as CC messaging and MPC which could afford a broader range of expressions and messages, but my current knowledge of OSC protocol is far more advanced. For the sake of other researchers/performers/composers to be able to better utilize the *Sonic Vessels* method, I intend on expanding the capabilities of the user interface to allow for a more broad range of use cases and implementations.

Networking

In order for this system to work as I have presented it, a strong WiFi network is required. This network handles the sending of physiological data and the wireless communication necessary for many performance situations. This requirement is certainly a limitation in terms of how and where these works can be presented. While I am inclined to keep much of this method within the framework of spaces where WiFi networks can be found, this also renders it nearly impossible in situations where this is not possible. Possible solutions would be to go completely wired for the communication or even developing a completely analog solution to the data communication. These solutions have both been discussed as future work which we intend on exploring when we can.

In terms of WiFi, we have also found issues when using a public WiFi network. This is mostly due to the fact that in a performance setting, any public WiFi will almost certainly have a large amount of data being sent through other users. This can cause lags or issues in terms of the data being sent properly to the devices and software. To alleviate this concern, we have always used our own private network for performances, often times using a physical connection for the most important devices (Max/MSP laptop, koto). This also presents a limitation in that not all performers or ensembles have access to their own network. Optimization of the data framework and a careful selection of which data is being sent can help with this. In some previous performances such as *Frisson Waves*, we nearly had a complete crash due to the sheer amount of data hitting Max/MSP. In subsequent performances, I have chosen to be more selective in what kinds of data and the number of discreet messages which I will look for.

Max/MSP, Eurorack, Instrument Choice

In all of my work, I utilize the Max/MSP software to serve as the brains of the setup in a sense. I have also used an extensive Eurorack synthesizer setup which I have been building over the past three years. Both of these instruments/objects are not free. In comparison to other DAW/software choices, Max/MSP does offer a reasonable cost but is still not a free program. It is also not something you can use on Linux machines. The best alternative for this is to use PureData, which was also developed by Miller Puckette. It is in many ways functionally the same

as Max/MSP, but it is free and also can be used on Linux machines. I am not personally very experienced in using PureData but in the future I will co-develop a full revision of the Max/MSP patchers I use within PureData in collaboration with Aaron Hynds. In terms of the Eurorack system, I chose this analog system as my main sound source for two main reasons:

1. The predominately analog approach served as an aesthetic connection for me, wherein the physicality of the involved people directly connects to the physicality of Eurorack objects.

2. Using a predominately analog system provides a nice balance between software and hardware integration as well as physical performative intervention.

However, there are some issues which come along with using this system. For one, Eurorack synthesizers require quite a lot of power. This power also generally needs to be firmly grounded, which can be an issue in some venues, especially here in Japan. We alleviated this concern a bit by using some portable power generators in some performances, although certain modules such as the Make Noise Pressure Points do not behave as expected when doing this. They are also quite cumbersome and heavy, which makes it nearly impossible to transport by oneself. Luckily, the transportation issues have not been a great deterrent thus far. The upside to this is that the Eurorack format lends itself quite well to being changed around based on the needs and limitations of the performer. Still, this is a concern which has to be addressed and remedied as per the specific user. The method itself does not strictly require the use of Eurorack synthesizers. Other users could easily apply these methodological approaches through any instrumentation or software they decide to. This would simply require the user to adapt the principles to their own distinct setup.

Along with the size and power issues found with Eurorack synthesizers, these are highly customized systems. Overall, each system will be unique in some way. Throughout this methodology, I have made an effort to break down the implementation in basic terms of elements which are common with most Eurorack systems: VCOs, envelopes, LFOs, effects, etc. This should alleviate some of the issues when adapting this method to each unique system. Still, it would be outside of my expectations for every artist or researcher to attempt to make a 1:1 copy of

the system I use. Instead, it is important to adapt the basic tenets of my method to the individual system.

6.2.2 Compositional Limitations

When composing for this method, there are some limitations which the creator will run into. These limitations are not so different than a typical issue which composers have to face: how to adapt and express their expressive intentions to the available set of sound objects/performers. The biggest issue that composers can expect to run into is the reduced agency and control over the resulting sound works as was discussed previously. Limitations can and should be set by the composer ahead of time to ensure that the possible resulting sounds will all fall within their intended sonic expression. This was explored heavily with many composers ranging from Gregorian chant all the way to current free jazz composers. However, the intention of how to implement the presence of the performers (via physiological sensing data) should be adequately taken into account. If the composer is simply placing the numbers arbitrarily, then the results may not in fact be so different than a simple random number generator. instead, it should be taken on by the composer to meaningfully direct this data to a path of sonification that can express something greater than arbitrary. This responsibility can offer up new sonic explorations but may also provide a challenging hurdle to navigate. I personally like to see this as an exciting hurdle to cross, but as with any challenge, it may also be seen as a detriment to the possible creativity being explored.

6.2.3 Performative Limitations

As a performer, using a new kind of performative approach can always be a challenge. Personally speaking, I tend to get stuck in what is comfortable and have to consciously push myself to explore new forms of performance and composition which fall outside of what is "comfortable". This is not a unique issue based on discussions I have had with many musicians and composers. However, this is not to say that it is a bad thing or even something that artists are inclined to avoid outright. Instead, it is simply something that takes time and energy to proceed with. While this in and of itself may not be a real limitation, a greater issue

arises: when the roles that we are used to and the gestures/musicality that we are trained with are challenged, even to a slight extent, how does our own agency and the agency of the ensemble as a whole shift? Therein lies, I believe, the limitation and concern with this method. When we are placed into an unusual or possibly uncomfortable performative situation, the dynamic between ourselves and our performative intention can become strained or preoccupied. Instead of focusing on the musicality and expressiveness of our work, we may find ourselves working hard to keep up or stay within the confines of the works being presented. This may not be all that much different than the challenges of live improvisation or reading an orchestral score for the first time, but when we include things such as physiological sensing, live electronics, and robotic instruments, the situation inherently changes in some way. I cannot say that I understand all of these new changes but as I have stated previously, this exploration of the relatively unknown is what provides much of the excitement for myself and for other professionals I have spoken with regarding this method.

6.3. Future Works

My future works will focus primarily on taking the method which I have presented and expanding it and refining it through several upcoming projects as well as continuations of my previous research works. There will also be further user studies and publication submissions which will help to guide and define the future of the *Sonic Vessels* system in both an academic and performative sense.

6.3.1 Bespoke Musical Objects

Based on the on-going development the bespoke robotic koto which was able to perform the physiological data of performers and audience members, I will continue to develop this particular instrument as well as engage in the development of new objects. This will include further development of the responsive open reel tape machine, a robotic yangqin (a Chinese string instrument which has roughly 144 strings, similar to a massive hammered dulcimer), and abstract objects similar to what was initially developed for *Phantom Undulations*. This continued development will focus on three main elements:

1. A more sophisticated and portable robotic actuation system.
2. A more comprehensive system for sonification via Max/MSP.
3. A more direct connection between the people engaging with these objects.

The development of the more sophisticated actuation system in currently in-progress with George Chernyshov handling the engineering and much of the fabrication along with Misha Pogorzhelskiy covering the design and fabrication as well, Aoi Uyama serving as an advisor for the traditional koto elements, and DingDing Zheng handling the physiological data application and implementation. This is the same team who developed the initial version of the robotic koto. The actuators are being completely redesigned and changed to solenoids which will provide a much quieter sound and an actuation method which is much closer to the traditional way a koto in plucked. Another substantial development will be in replacing the actuation method in which the strings are bent to produce an altered pitch. Currently, they are being pulled from the bottom and all strings can only change the pitch of the strings by one half step. The new design will depress the strings from the top and have a more precise actuation method which will allow for a more varied range of pitch changes (microtonal steps, up to a whole step or even minor third in some strings). Finally, the entire robotic mechanism will be designed so that it is feasible to transport it easily and even allow for other performers to attach it to their own koto. In terms of future performances, we are currently holding semi-regular live performances with Yūgen Ensemble, the performance group consisting of myself on Eurorack synthesizers, Aoi Uyama on koto, and Juling Li on erhu. Thus far, all of our performances have featured the robotic koto and we will continue to develop new repertoire for the ensemble that utilizes this robotic object/physiological data connection. Subsequent official recordings and performances will continue throughout 2024.

Developing the sonification system for Max/MSP will continue from where I am currently at, with the initial focus on new ways in which the data can be applied which I was not able to implement fully prior to the writing of this thesis. This will mainly consist of expanding upon the existing data we are able to detect as well as the exploration of alternate forms of physiological sensing, such as EEG and thermal cameras. For the sake of clarity and focus, I centered my thesis research

mostly on HRV and EDA, but will continue to branch out and incorporate more ways in which we can detect, interpret, and implement the presence and being of the people involved.

Future installation exhibits and similarly object-based works will expand my current research into more tactile ways of representing these *vessels* as a presence representation. My concern regarding a lack of concrete focus caused me to not spend too much of my time on the object-based installation works such as *Phantom Undulations* and *Ephemeral Counterpoint*. I am happy that I was able to incorporate this approach to an extent with this thesis research, but my intention is to utilize this approach more frequently in my future works and allow myself to fully explore the possibility of using inanimate objects to represent the liveness of performers, audience members, or something new that I cannot imagine right now.

6.3.2 Responsive Score Development

While developing this responsive system for musical performance works, I began to find myself increasingly interested in how this kind of system could be exploited to visualize and direct performers. The musical score is one of the most common and direct ways of guiding performers in executing and interpreting a musical work. Therefore, I have begun to develop a visual means of showing this data in a meaningful way for a more direct and flexible interpretation. So far, this system consists of a rather simple visual indicator which shows the performers the relaxation and engagement levels of the performers in one group and the audience in another. While this is still a somewhat simple method, I intend on continuing the development of this system to become a fully-integrated and responsive aspect of the *Sonic Vessels* method.

The first implementation of this responsive score was utilized in a live performance in July 2023 at Bar Transit in Hiyoshi, Japan (see Chapter 4 for more on this). Based on the feedback of this performance, I have started to shift towards a more abstract method of visualizing the physiological data to better allow the performers to incorporate their own interpretation of the data. Much of the inspiration for the visual language I am using is based on the graphic scores of composers such as Iannis Xenakis, Krzysztof Penderecki, and Karlheinz Stock-

hausen. Furthermore, the recent works of contemporary composer and performer Marta Tiesenga are being referenced in terms of visual language and intention.

In *Spectral Counterpoint*, a heavily abstract score will be shown to the performer (myself) which will show the incoming physiological data of the remote participants. This score will serve as a visual aid to the experience which the remote participants are having. As was discussed previously in regards to this performance work, the role that the I as the performer have extends beyond simply performing music in a live setting. These real-time experiences of the remote participants will have a direct effect on the possibilities which I have in the performance and I will take on a sort of conductors role. In other words, I will be performing while guiding and directing the experiences of the remote participants, much like an orchestral conductor guides the musicians.

Another live score work which is currently in development and will be debuted in the spring of 2024 will feature a traditional Japanese music ensemble. With this ensemble, the physiological data of the performers (currently 2 kotos, 1 biwa, 1 shamisen, 1 shakuhachi, and 1 shō) will be gathered in real-time and then utilized in a visual score to guide the performers. In order to do this, I will be familiarizing myself with the traditional approach to musical notation as it pertains to traditional Japanese music and presenting this visual aid as a mixture of traditional Japanese notation and abstract visual cues. Following the success of *Innermost Echoes*, my intention is to further explore the traditional Japanese music style as a jumping off point for a more experimental and ambient musical and performative system.

In Spring 2024, a new performance will be given at CalArts in Santa Clarita, California at the Wild Beast. This performance, consisting of Kozue Matsumoto, Patrick Shiroishi, and Shoshi Watanabe, will fully test out a more comprehensive and flexible visual system. I will also contribute a Max/MSP patcher which will create atmospheric and abstract sound design along with the adaptive score. This system will be relying on a mixture of their live physiological data in the Wild Beast as well as my remote data which will be incorporated via a website, much like *Phantom Undulations* and *Spectral Counterpoint*.

6.3.3 Ephemeral Temperament

Ephemeral Temperament is an on-going study in tuning systems and Temperament which is fluid and based on physiological sensing data, performative outcomes, external inputs, or any combination of the above. The goal of this study is to develop a new and novel musical language based upon this fluctuating input system. The main outputs which will be explored within this fluid Temperament will be:

1. A performance structure affording the production, performance, and recording of fluidly tempered sonic structures.

2. A generative score system for visualizing these fluctuating tuning systems for live musicians and other performative artists.

3. A comprehensive study into the affect of these novel tuning structures consisting of user studies, live performance workshops, and numerous performance studies with outside artists.

To date, I have already begun to explore the first item through the work *Spectral Counterpoint*, which was discussed in detail in Chapter 4. It will be the main component of upcoming *Spectral Counterpoint* performances which will be held in early 2024. To realize this system, I based it primarily within Max/MSP in the form of a series of mathematical elements which take incoming data (predominately physiological data) and map this data to a number of different patcher elements, including: pitch controls for waveforms, pitch-to-MIDI converters intended for the Eurorack system, and ADSR envelopes for both internal and external sound sources. By maintaining the mathematical and control interface within Max/MSP, it allows for this tuning system to be widely used in various applications which can accept either OSC or MIDI messages.

The generative score element of this work is partially completed through the use of graphic score elements which were developed for *Innermost Echoes* and *Spectral Counterpoint*. However, much further work and consideration must be taken when presenting this adaptive score to live acoustic musicians, especially within the context of more (for lack of a better term) traditional performance settings. One such example is the future intention of presenting orchestral works with this

adaptive tuning system. While it is rather safe to present microtonal notation to professional musicians of most disciplines, there are certain issues which can arise in terms of presenting a score which can change with each performance/rehearsal. Some instruments would require special setup or preparation to be able to achieve these kinds of non-traditional/uncommon tuning systems. Therefore, additional care and consideration is being taken in order to limit these kinds of issues. One method of limiting these issues would come from the compositional perspective in the limitation of possible gestures depending on the instrumentation. For instance, if certain uncommon notes/frequencies would be extremely troublesome for the tenor trombone but quite easy for the cello, these situations could help to determine which notes and gestures each instruments would even be allowed to see the gestures. Another practical concern is that of the conductor's score. As was discussed previously in Chapter 4 and Chapter 5, the conductor would require the ability to see the entire score at any given moment to properly carry out their role as the leader of the ensemble. While having the two-page generation of the score (current page and next page) would assist in this, a more thoughtful approach to the conductor's score is being developed currently. Most likely, it will consist of a similar generative template as the musician's score with some additional information for the conductor, such as an additional page/time duration so that they can prepare for their cues.

6.4. Social Impact

As with most of my work, I tend to not think actively about how it may have some kind of social impact in the early development of the work. This is not to say that I have any aversion to presenting social impact or critique. Instead, I generally do not actively think about this in the beginning, but instead let this aspect come about naturally and organically as I develop the works from a purely aesthetic or artistic angle. With this *Sonic Vessels* method, I do believe that there are several aspects which can have a great contribution and social impact.

Better Understanding Presence and Expression

One of the biggest contributions is to develop a stronger understanding of how presence, whether physical or remote or a mixture of the two, can be utilized as an artistic, expressive, or melodic voice within sonic works. While many great artists have engaged with and developed systems for giving audiences or users a voice in sonic works, I believe that the *Sonic Vessels* approach can afford a deeper understanding of how our roles as audience/performer/composer can be broken down and reconfigured into a more democratic and equal stance. If the separation between these often distinct roles can be stripped away, we can create experiences which are much more conversational and equally shared between everyone involved. Within the right context, this approach could afford the ability for people, regardless of their musical training or societal position, to engage in these works and see themselves in new contexts.

Heightened Understanding of Traditions and Cross-Cultural Works

In addition, my work with *Innermost Echoes* has began an exploration of the traditions found within Japanese music, especially gagaku. Although collaborations involving Western and Japanese composers and performers has been done quite extensively over the years, I believe that exploring this connection alongside novel technological applications can provide a deepening of appreciation for these different yet in many ways similar musical traditions. Much of my exploration with this approach has been done alongside professional koto/shamisen player and researcher Aoi Uyama, whose years of experience in the field of traditional Japanese music has provided a strong background for our work. In addition to my work with Aoi, I have also regularly collaborated with Kozue Matsumoto, another traditional Japanese musician based in Los Angeles and whose work also shifts into more experimental and improvisational areas. Establishing this strong connection to the traditions of Japanese music will help to shape our future works as something that can present a new approach to traditional musics while honoring the music and methods which have come before.

Platform for Differently Abled Artists

One future work which is in the early stages of development will take my method and apply it to performers and composers who are differently abled. In this investigation, my focus is to allow people whose physical bodies present difficulties in performing or composing to engage meaningfully in the creating and performance of sonic works. This will be done by utilizing the incoming physiology and presence of these individuals and applying it to all of the sonic and performative parameters. Rather than simply allowing their presence to create a 1:1 effect, a suitable interface for this interaction is being developed to allow them to customize and route all of this information as they please. Presenting this work would be of benefit to people who were formerly performers of composers but now have physical difficulties in continuing to do so, while it could also easily be utilized by people who's situations have prevented them from ever engaging in the creation and performance of music. In these works, my intention is to simply provide the tools and platform for them to create their own inspiring works, which will include digital sound creations within Max/MSP, works which utilize analog synthesizers, and bespoke musical artifacts such as the robot koto and others. In all, my desire for this project is to reach out to people who's situations make it difficult to express their ideas sonically and allow for them to become directly engaged in live musical works or recorded works.

Outreach Across Disciplines and Audiences

Another important social impact which my work can offer is an extended dialogue and outreach across disciplines and audiences. Much can be said for projects which fuse technologists, academics, musicians, and people across a variety of disciplines. With my *Sonic Vessels* methodology, this collaborative approach is inherently bound to the approach itself. This is not a method designed for purely musical or purely scientific explorations. Rather, it is designed to allow a flexible and interpretive structure by which artists and makers from any discipline can produce their own meaningful results from it. This method is based on empirical data analysis, qualitative analysis, and in-the-wild presentations which provides a strong backing for the validity and meaningfulness of it.

Deeper Appreciation for Physiology and Musical Experiences

Finally, the physiological data analysis which we have undertaken with the works discussed here have begun to give us a much more clear view of how physiology and musical experiences (both from the performers and audiences perspectives) are intertwined. In our early work, much of this analysis was focused on the audience and how their current states can be shown through sound, lights, and projections. However, as I began to focus more on my thesis method, the emphasis shifted more towards the performer's experience as I have discuss. Although this focus is in fact heavily tied to the performer, the data we have collected and discovered through numerous publications and conference demonstrations has presented some exciting insights into how live music and physiology can be combined to give a better understanding of how we experience sound and music from many angles. Taking this knowledge, we can provide more curated, focused, and intentional works which can have a greater impact on the people involved and provide a more immersive and affective experience in general.

Industry Perspectives

In the process of developing this method, I had the opportunity to speak with several professionals in the music industry and get their invaluable insights into my work. Some of those I spoke with have had a direct interaction with the method, while others were given the platform and asked how they would plan on using it in their own work. One such professional was Evan Marien, a bassist, composer, producer, and visual artist. Based in New York, Evan has built his career on the fusion on many genres of music through his highly skilled bass playing along with the incorporation of electronics and live visuals. He expressed an interest in utilizing this method as a way to heighten the collaborative nature of his work and to gain new insights into the inner workings of himself while performing. Another performer who has expressed an interest in utilizing this method in their own work is Bobby Hawk, an acclaimed studio musician, performer, and composer. In his words, he sees this method as a direct way to tap into some new kinds of discoveries in his already storied improvisational work. Claire Taylor, principal bassoonist of the Millikin-Decatur Symphony Orchestra and educator of a wide range of students, expressed her interest in how this method could facilitate a stronger

learning experience for budding musicians and their comfort level in improvising. Furthermore, she stated that externalizing the presence of the performer onto musical artifacts could help facilitate a deeper understanding for the performers and the audience alike.

Two of the people whom I spoke with had the chance to see this method put into practice here in Japan. One such person was Ryo Harada, a spatial audio specialist. He attended two of the performances of *Innermost Echoes* as well as the gallery showing of *Ephemeral Counterpoint*. His thoughts focused on how the use of the robotic koto and live biodata did not deter from the audience experience despite not knowing exactly how this data was being implemented. He further discussed how this method was still able to facilitate a connection between the performers and the audience even though this externalized presence was more focused on performer to performer interactions. Another attendee of the Bar Transit performance of *Innermost Echoes* as well as a subsequent performance featuring the robotic koto was bassist and interviewer Akira Sakamoto. He discussed how the audience being wired up to data sensors added to a sense of connectedness with the performers, and also stated that there is a lot of potential for this methodological approach. He also discussed how more could be done with the implementation of the Eurorack system and the overall comfort level of the performers interacting with this system.

Overall, these industry perspectives helped me to gain insights into the things which work well with the method and the things which stand to be improved in the future. For anyone who is interested, these full statements are available to view in the Appendix.

Chapter 7
Conclusion

The main purpose of developing *Sonic Vessels* is to present a methodology by which affective sonic experiences could be created which use the perception of the performer or composer as its own performative role. Throughout this thesis, I have presented each step of the development of this method, from the initial inspirations which started it all, all the way to the final analysis and discussion. As the method developed, the manner in which the research was conducted allowed for a mixture of qualitative and quantitative discoveries. This blended research approach was crucial to allowing the method to come about in a naturally musical and expressive way while also ensuring that empirical data would support the work.

Undertaking this size of project necessitates that a deep look into what has come before, especially in terms of musical and performative literature. This exploration into the prior canon of influential works covered a wide range of fields. Beginning with the concept of liveness, the literature review first focused on the implementation of avatars in music. This was popularized in part by fully virtual idols such as Hatsune Miku as well as hybrid human/virtual works by English group Gorillaz. This virtual avatar performance approach allows the original artists to be able to express things in a way that humans simply could not do. While these avatar representations do not possess a physical body, the other side of this equation would be to delve into the physicality of performers as a means of expressing or performing. In most musical styles, the physical movements of the performers have some kind of impact on their expressions and the on-stage unspoken dialogues which occur. Even though this can vary from genre to genre, and even performer to performer, these oftentimes greatly nuanced physical aspects are an important aspect of live performance.

Utilizing unique instruments and compositional and performative approaches has a long and rich history. Whether it is the robotic works of Chico Macmurtrie or

Captured by Robots, the improvisational approaches of early Greek music all the way to current jazz practices, or the experimental approach to sonic improvisation proposed by Joan La Barbara, the tools and practices we use as performers and composers has been developing since the early days of civilization. The roles that each of us have in these performance paradigms is something that is also fluid and based upon many works and researches previously undertaken. My work explores this and provides a way to challenge these roles while acknowledging what came before it.

The use of technology in musical works is another field which has been very impactful on this research of mine. One of the earliest influential technological applications of music was that of *musique concrète*, which was founded in part by Pierre Schaffer. The name is derived from the concept of "music made with fixed sounds, unconcerned with the origin of the sounds it uses" [40]. Shortly after the formation of *musique concrète*, another stylistic and aesthetic approach to music came in the form of *elektronische Musik* which was greatly developed by composer Karlheinz Stockhausen. This manner of composition focused on the use of electronic signals and utilized things such as oscillators. Herbert Eimert stated in 1956 that electronic music is comprised of electronically produced sounds, exists only on recorded tape, and can only be realized through a loudspeaker system [44]. This narrow definition of the genre shows how despite some similarities to *musique concrète*, the two approaches are actually quite dissimilar.

When it comes to physiological data and musical works, there have been quite some researches carried out which explore EEG, including *PsychDome* and *Music Emotion Capture*. Utilizing physiological sensing as a means for detecting and observing physiology while listening to or engaging with music has also proven to be extremely useful over the years. In recent years and at this very moment, many artists are exploring their own unique musical dialogues through the novel application of technologies. A few leading artists in their work are Björk, Arca, Holly Herndon, and Endel. Whether they are working with or alongside AI, spatial sound, physiological sensing, or many other technological means, their intention and exploration always focuses heavily on the musical and aesthetic presentation which they produce.

This method of mine, *Sonic Vessels*, is rooted in the concept of presenting the

passive presence, or *liveness*, of performers and composers. This presentation of presence is the main vehicle for producing novel performance practices. New performative dialogues, hierarchies, compositional approaches, and performative interventions are all inherently tied to this concept. Representing or externalizing the *liveness* of the performer allows for a direct collaboration with their own presence. For instance, a violin player performs a "solo" piece while their passive presence is sonified through a robotic piano. While there are in fact two sound producers in this performance, would this still be a solo piece? Is it a duet? Is it neither or both?

Three main points to consider when looking at *Sonic Vessels* have to do with how real-time the performance itself is, whether the performers are responding actively or passively, and whether or not a performer is even there at all. Lifting the restrictions on previously held performance practices allows for greater freedom while also placing certain limits on the process. For instance, a performer cannot realistically control their own pnn50 levels, so this data would be referred to as passive. This passive data is what is extremely vital to the sonification which is at the core of this method. Throughout my research, I divided my approach to strengthening and validating my concept into two main research directions: Externalized Performer Presence and New Compositional Methods. The first direction focused more on how to gauge this presence, how to implement the data as a sonic generator, and the affect on agency which this approach would facilitate. The second direction was more squarely focused on the new ways to compose and perform alongside this method. New performative roles and hierarchies were certain to emerge from this kind of approach and the *Sonic Vessels* concept and methodology are no different.

The four principle conceptual points of *Sonic Vessels* are:

1. Time-Domain: The ways in which time and location play a factor in the presentation of these works.

2. Passive Presence: The ways in which the presence, or *liveness*, of the performers and participants is shown.

3. Musical Artifacts: The external objects which will sonify the presence and responses of the participants and/or performers.

4. Performative Dialogue: The ways in which the performers will interact with and respond to the elements listed above.

The implementation and development of this method began with some preliminary collaborative works which allowed me to road-test elements of my method in public performances and installations. These included works with Stelarc, SenSen Mu, Friendred, and Mademoiselle Cinema. I also conducted a sound affect user study which offered invaluable insights into how people perceive a broad range of sounds, which guided me in the early implementation of data into sound. Several main works of mine were presented as core implementations of the *Sonic Vessels* method. These included the bespoke robotic koto project *Innermost Echoes*, the remote installation work *Phantom Undulations*, and the remote/non-linear performance work *Spectral Counterpoint*. Each of these projects provided a focus on certain aspects of the overall concept and method, and each consecutive presentation took what was learned from the previous performances. This way, each time it was presented live was more informed and intentional than the previous ones.

With each main live performance, physiological data was retrieved for post-performance analysis. This empirical data analysis provided some strong findings which correlated with the *Sonic Vessels* implementations. This was especially true for the Bar Transit performance, where the method elements that were added all appeared to coincide with rises in pnn50. Another extremely significant finding was that of the comparison between the two Media Studio performances. The first tone did not use data and the second one used the performers data. We could see in the data a highly significant difference in RMSSD between these two performances. With the only difference between these two being the implementation of the *Sonic Vessels* system of data sonification, this discovery was rather validating.

Much of the discussion around my evaluation was focused on performative and compositional choices and concerns. When utilizing this kind of broad system, it will inherently change the manner in which you approach your work. One such change is in the role of composer when certain aspects are no longer in the control of the composer themself. This control parameter ends up becoming directly related to the presence of the performer. Is this sense of presence meant to inspire or is it meant to be something left open to interpretation? Is it meant to be known at all, or simply something that exists intrinsically within the performance

dynamic?

Overall, this *Sonic Vessels* methodology is intended to inspire new performative and compositional dialogues by which novel performances and sonic experiences will be developed. While it started simply enough with some preliminary works, it has since opened up into a rather expansive and flexible system of sonic expression and affect. Despite some minor things which did not work out as planned (Augmented Humans remote data feed was not deployed, one of the intended data applications was not successful according to the data, some of the robotic koto functionality is not as flexible as I would like), this methodological approach to sonic liveness has been successful. I have been able to validate that this method is capable of creating new and novel forms of performances which was validated through both qualitative and quantitative analysis, as well as opinions from industry experts who have shown an interest in working with this method.

This work that I have presented is the beginning of what will be a long process of dissecting and exploring performance practice theory and sonic affect. Each aspect which I have explored in this work would still have room for further exploration with different perspectives and intentions. Much of what has been done in terms of experimental and novel musical practices rests on the process of constant reworking of materials. This is true also for my presented live works. The more these works are presented in public, the stronger they will be become. It is in this strength that I envision the future of this work. As the process of *Sonic Vessels* becomes more and more second nature, continuously evolving dialogues will run alongside this experience. Much like a professional jazz musicians, the music itself may remain similar in genre or style but the expertise constantly evolves. The longer that myself, performers, and composers explore this *Sonic Vessels* method in-the-wild, the more informed, matured, unwieldy, and evocative it will become. Much like a fading memory captured on a VHS tape, it will always at its core be this same method but over time it will slowly morph into something new: a method which is inherently connected to its origin but beholden to the participatory process of its development. Simply said, this method is the seed of something which cannot be known right now but in some ways is already here. A particular point on a circular timeline of affect, liveness, and sonic perception.

Publication List

1. ***Innermost Echoes: Integrating Real-Time Physiology into Live Music Performances***; **Danny Hynds**, George Chernyshov, DingDing Zheng, Aoi Uyama, Juling Li, Kozue Matsumoto, Michael Pogorzhelskiy, Kai Kunze, Jamie Ward, Kouta Minamizawa; TEI; February 2023.

2. ***Innermost Echoes***; **Danny Hynds**, George Chernyshov, DingDing Zheng, Aoi Uyama, Michael Pogorzhelskiy, Kozue Matsumoto, Martin Velez, Tatsuya Saito, Kai Kunze, Kouta Minamizawa, New Interfaces for Musical Expression (NIME), Music Track, May-June 2023.

3. ***Phantom Undulations: Remote Physiological Sensing in Abstract Installation Works.***; **Danny Hynds**, Dingding Zheng, Yilin Zhang, Hua Ma, Kirill Ragozin, George Chernyshov, Jamie A. Ward, Tatsuya Saito, Kai Kunze, and Kouta Minamizawa. In Proceedings of the Augmented Humans International Conference 2023, pp. 367-370. 2023. Proceedings of the Augmented Humans International Conference 2023.

4. ***Frisson Waves: Exploring Automatic Detection, Triggering and Sharing of Aesthetic Chills in Music Performances***; Yan He, George Chernyshov, Jiawen Han, Dingding Zheng, Ragnar Thomsen, **Danny Hynds**, Muyu Liu, Yuehui Yang, Yulan Ju, Yun Suen Pai, Kouta Minamizawa, Kai Kunze, and Jamie A. Ward; IMWUT; September 2022.

5. ***Linking Audience Physiology to Choreography***; Jiawen Han, George Chernyshov, Moe Sugawa, Dingding Zheng, **Danny Hynds**, Taichi Furukawa, Marcelo Padovani, Kouta Minamizawa, Karola Marky, Jamie A Ward, and Kai Kunze; TOCHI; May 2022.

6. ***ImageFlowing-Enhance Emotional Expression by Reproducing the Vital Signs of the Photographer***; Mu Qianqian, Chernyshov George,

Wang Ziyue, **Danny Hynds**, Zheng Dingding, Minamizawa Kouta, Chen Dunya, Ueki Atsuro, Inakage Masa, Kunze Kai; SIGGRAPH Emerging Technologies; July 2022.

7. ***Frisson Waves: Sharing Frisson to Create Collective Empathetic Experiences for Music Performances***; Yan He, George Chernyshov, Dingding Zheng, Jiawen Han, Ragnar Thomsen, **Danny Hynds**, Yuehui Yang, Yun Suen Pai, Kai Kunze, and Kouta Minamizawa; SIGGRAPH Asia 2021 Emerging Technologies; December 2021.

8. ***Tactile Music Toolkit: Supporting Communication for Autistic Children with Audio Feedback***; Di Qi, **Danny Hynds**, Mina Shibasaki, Yun Suen Pai and Kouta Minamizawa; IEEE World Haptics Conference (WHC); July 2021.

9. ***Haptic Empathy: Conveying Emotional Meaning through Vibrotactile Feedback***; Yulan Ju, Dingding Zheng, **Danny Hynds**, George Chernyshov, Kai Kunze, and Kouta Minamizawa; CHI Extended Abstracts; May 2021.

10. ***Boiling Mind - A Dataset of Physiological Signals during an Exploratory Dance Performance***; Zhuoqi Fu, Jiawen Han, Dingding Zheng, Moe Sugawa, Taichi Furukawa, George Chernyshov, **Danny Hynds**, Marcelo Padovani, Karola Marky, Kouta Minamizawa, Jamie A Ward, and Kai Kunze; Augmented Humans; February 2021.

11. ***Boiling Mind: Amplifying the Audience-Performer Connection through Sonification and Visualization of Heart and Electrodermal Activities***; Moe Sugawa, Taichi Furukawa, George Chernyshov, **Danny Hynds**, Jiawen Han, Marcelo Padovani, Dingding Zheng, Karola Marky, Kai Kunze, and Kouta Minamizawa; International Conference on Tangible, Embedded, and Embodied Interaction (TEI); February 2021.

12. ***KABUTO: Inducing Upper-Body Movements using a Head Mounted Haptic Display with Flywheels***; Taku Tanichi, Futa Asada, Kento Matsuda, **Danny Hynds**, and Kouta Minamizawa; SIGGRAPH Asia Emerging Technologies; December 2020.

13. ***Sophroneo: Fear not. A VR Horror Game with Thermal Feedback and Physiological Signal Loop***; Kirill Ragozin, Dingding Zheng, George Chernyshov, and **Danny Hynds**; CHI Conference on Human Factors in Computing Systems; April 2020.

Exhibition List

1. ***Spectral Counterpoint***; CyberLivingLab, Odaiba, Japan; November 16, 2023.

2. ***Recitations & Fading Memories***; UltraSuperNew Gallery, Harajuku, Japan; October 19, 2023.

3. ***Innermost Echoes***; VRSJ Conference, Hachioji, Japan; September 12, 2023.

4. ***Innermost Echoes***; Bar Transit, Hiyoshi, Japan; July 21 2023.

5. ***Innermost Echoes***; KMD Media Studio, Hiyoshi, Japan; May 19 2023.

6. ***Boiling Mind III*** (by Moe Sugawa/Mademioselle Cinema/Embodied Media/Geist); SESSION House, Kagurazaka, Japan; April-June 2023.

7. ***Corporeal Counterpoint*** (by Stelarc and KMD); KMD Media Studio, Hiyoshi, Japan; April 3, 2023.

8. ***Innermost Echoes***; KMD Forum, Tokyo, Japan; October 29-30, 2022.

9. ***Image Flowing*** (by SenSen Mu); *SIGGRAPH* E-Tech; Vancouver, Canada; August 8-11, 2022.

10. ***Innermost Echoes***; *Recombinant* exhibit; ANB Tokyo, Roppongi, Japan; June 24-26, 2022.

11. ***Ephemeral Counterpoint***; *Recombinant* exhibit; ANB Tokyo, Roppongi, Japan; June 24-26, 2022.

12. ***Moving Photon*** (by Friendred Peng); Ugly Duck, London, England; January 2022.

13. ***Frisson Waves*** (by Yan He); Karuizawa Concert Hall; Karuizawa, Japan; April 2022.

14. ***Kōzo/Mitsumata/Gampi*** (by Tatsuya Saito); Ino-Cho Paper Museum, Kochi, Japan; October 2021.

15. ***Sonitecture: Module I***; Media Ambition Tokyo, Roppongi, Japan; May 2021.

16. ***David Lynchenborough***; CalArts Digital Arts Expo, Valencia, California; May 2020.

17. ***Boiling Mind II*** (by Moe Sugawa/Mademoiselle Cinema/Embodied Media/Geist); SESSION House, Kagurazaka, Japan; March 2020.

References

[1] Theodor W Adorno and Rodney Livingstone. Form in the new music. *Music Analysis*, 27(2/3):201–216, 2008.

[2] Iain A Taylor, Sarah Raine, and Craig Hamilton. Covid-19 and the uk live music industry: a crisis of spatial materiality. *The Journal of Media Art Study and Theory*, 1(2):219–241, 2020.

[3] François Bonnet and Bartolomé Sanson. *Spectres II: Resonances*. Shelter Press, 2020.

[4] Atau Tanaka and Marco Donnarumma. The body as musical instrument. *The Oxford handbook of music and the body*, pages 79–96, 2019.

[5] Peggy Phelan. *Unmarked: The politics of performance*. Routledge, 2003.

[6] Jerrold Levinson. Evaluating music. *Revue internationale de philosophie*, pages 593–614, 1996.

[7] Herbert Brün. Technology and the composer. *Interpersonal relational networks*, page 1, 1971.

[8] Burcu ÖLGEN. Journal of strategic research in social science. *Science*, 5(3):15–22, 2019.

[9] Holly Rebecca Herndon. *Proto*. Stanford University, 2019.

[10] Henry Bruce-Jones. Holly herndon sings to her a.i. baby on new album proto, Mar 2019. URL: `https://www.factmag.com/2019/03/11/holly-herndon-proto/`.

[11] James Blake and Endel. Wind down, May 2022.

[12] Bruce Ellis Benson. *The improvisation of musical dialogue: A phenomenology of music*. Cambridge University Press, 2003.

[13] Stephen Coleman. Music as dialogue. 2002.

[14] Oded Ben-Tal and Caroline Wilkins. Improvisation as a creative dialogue. *Perspectives of New Music*, 51(1):21–39, 2013.

[15] David A Camlin. 'this is my truth, now tell me yours': emphasizing dialogue within participatory music. *International Journal of Community Music*, 8(3):233–257, 2015.

[16] Sarah Fuller. Tendencies and resolutions: The directed progression in" ars nova" music. *Journal of Music Theory*, 36(2):229–258, 1992.

[17] William G Waite et al. The rhythm of twelfth-century polyphony, its theory and practice. *(No Title)*, 1954.

[18] Scott Reeves and Tom Walsh. *Creative jazz improvisation*. Taylor & Francis, 2022.

[19] Jeff Pressing. Cognitive processes in improvisation. In *Advances in Psychology*, volume 19, pages 345–363. Elsevier, 1984.

[20] J Peter Burkholder, Donald Jay Grout, and Claude V Palisca. *A history of western music: Tenth international student edition*. WW Norton & Company, 2019.

[21] Carol S Gould and Kenneth Keaton. The essential role of improvisation in musical performance. *The Journal of Aesthetics and Art Criticism*, 58(2):143–148, 2000.

[22] Ingrid Monson. Hearing, seeing, and perceptual agency. *Critical Inquiry*, 34(S2):S36–S58, 2008.

[23] Joan La Barbara. Essence of improvisation. In *Spectres IV*. Shelter Press, 2023.

[24] Philip Alperson. On musical improvisation. *The Journal of Aesthetics and Art Criticism*, 43(1):17–29, 1984.

[25] Kenneth E Prouty. The "finite" art of improvisation: Pedagogy and power in jazz education. *Critical Studies in Improvisation/Études critiques en improvisation*, 4(1), 2008.

[26] Pedro Falcon. The historical development of concert pitch in the usa orchestras.

[27] Bruce Haynes. *A history of performing pitch: the story of'A'*. Scarecrow Press, 2002.

[28] Gordon W Binkerd. Walter piston. orchestration (book review). *Journal of the American Musicological Society*, 8:138, 1955.

[29] S Frederick Starr. A jazz musician's take on america's symphony orchestras. *HARMONY-DEERFIELD-*, pages 53–60, 2001.

[30] Daniela Veronesi. *The Art of Conduction: A Conduction Workbook*. Karma, 2017.

[31] Erin M Bonski. Ensemble playing and improvisation with soundpainting. *The American Music Teacher*, 67(4):59–60, 2018.

[32] Anders Eskildsen. The art of conduction: A conduction workbook and ensemble playing and improvisation with soundpainting. *Critical Studies in Improvisation/Études critiques en improvisation*, 12(1), 2017.

[33] Jenny Hans. Cymatics: A study of wave phenomena and vibration, 2001.

[34] Meara O'Reilly. Björk: Biophilia. URL: `https://mearaoreilly.com/Bjork-Biophilia`.

[35] Nomi Epstein. Musical fragility: A phenomenological examination. *Tempo*, 71(281):39–52, 2017.

[36] `https://www.britannica.com/art/Aeolian-harp.` Accessed: 2023-11-29.

[37] Christoph Riedweg. *Pythagoras: His life, teaching, and influence*. Cornell University Press, 2008.

[38] Lotfi Romdhane and Saïd Zeghloul. Al-jazari (1136–1206). In *Distinguished Figures in Mechanism and Machine Science: Their Contributions and Legacies, Part 2*, pages 1–21. Springer, 2009.

[39] Thom Holmes. *Electronic and experimental music: technology, music, and culture*. Routledge, 2012.

[40] Michel Chion. The state of musique concrete. *Contemporary Music Review*, 8(1):51–55, 1993.

[41] Carlos Palombini. Machine songs v: Pierre schaeffer: From research into noises to experimental music. *Computer Music Journal*, 17(3):14–19, 1993.

[42] Carlos Palombini. Pierre schaeffer, 1953: towards an experimental music. *Music & Letters*, 74(4):542–557, 1993.

[43] Marietta Morawska-Büngeler. *Schwingende Elektronen: eine Dokumentation über das Studio für Elektronische Musik des Westdeutschen Rundfunks in Köln, 1951-1986*. PJ Tonger, 1988.

[44] Herbert Eimert, Karlheinz Stockhausen, and Hans G Helms. *Electronic music*, volume 601. National Research Council of Canada, 1956.

[45] Emily Thompson. *The soundscape of modernity: architectural acoustics and the culture of listening in America, 1900-1933*. MIT press, 2004.

[46] Jonathan Sterne. Space within space: Artificial reverb and the detachable echo. *Grey Room*, (60):110–131, 2015.

[47] Sara Adhitya and Daniel Scott. The london soundmap: Integrating sonic interaction design in the urban realm. In *Proceedings of the Audio Mostly 2018 on Sound in Immersion and Emotion*, pages 1–7. 2018.

[48] Garth Paine. Sonic immersion: Interactive engagement in real-time immersive environments. *SCAN Journal of Media Arts and Culture*, 4(1):1–13, 2007.

[49] Ailbhe Warde-Brown. Waltzing on rooftops and cobblestones: Sonic immersion through spatiotemporal involvement in the assassin's creed series. *Journal of Sound and Music in Games*, 2(3):34–55, 2021.

[50] Jens Blauert. *Spatial hearing: the psychophysics of human sound localization*. MIT press, 1997.

[51] Arnold Whittall. Anton von webern: A chronicle of his life and work, 1980.

[52] Maria Anna Harley. Spatial sound movement in the instrumental music of iannis xenakis. *Journal of new music research*, 23(3):291–314, 1994.

[53] Yannick Guédon. Between presence and absence. In *Spectres IV*. Shelter Press, 2023.

[54] Patrick Zanon and Giovanni De Poli. Estimation of parameters in rule systems for expressive rendering of musical performance. *Computer Music Journal*, 27(1):29–46, 2003.

[55] R Keith Sawyer. Music and conversation. *Musical communication*, 45:60, 2005.

[56] Heather Maureen Pitcher. The harmonies of diversity, an exploration of transcendence and spiritual communication as unifying elements of musical culture. Master's thesis, 2001.

[57] Mireille Besson and Daniele Schön. Comparison between language and music. *Annals of the New York Academy of Sciences*, 930(1):232–258, 2001.

[58] Sergio Canazza, Giovanni Poli, Antonio Rodà, and Alvise Vidolin. An abstract control space for communication of sensory expressive intentions in music performance. *Journal of New Music Research*, 32(3):281–294, 2003.

[59] Giovanni De Poli, Antonio Rodà, and Alvise Vidolin. Note-by-note analysis of the influence of expressive intentions and musical structure in violin performance. *Journal of New Music Research*, 27(3):293–321, 1998.

[60] Giovanni De Poli. Analysis and modeling of expressive intentions in music performance. *Annals of the New York Academy of Sciences*, 999(1):118–123, 2003.

[61] Kevin McElhone. *Mechanical music*, volume 333. Osprey Publishing, 2004.

[62] Jason Richards. Bjork talks about how nature inspired her new, high-tech album, Oct 2011. URL: `https://www.theatlantic.com/entertainment/archive/2011/10/bjork-talks-about-how-nature-inspired-her-new-high-tech-album/246281/`.

[63] Danny Gallagher. Jay vance may play metal with homemade robots, but he says it's not meant to be funny, Nov 2017. URL: `https://www.dallasobserver.com/music/jay-vance-frontman-of-captured-by-robots-on-how-he-turned-his-novelty-robot-band-into-a-serious-one-10081744`.

[64] Ajay Kapur, Michael Darling, Dimitri Diakopoulos, Jim W Murphy, Jordan Hochenbaum, Owen Vallis, and Curtis Bahn. The machine orchestra: An ensemble of human laptop performers and robotic musical instruments. *Computer Music Journal*, 35(4):49–63, 2011.

[65] George Langroudi, Anna Jordanous, and Ling Li. Music emotion capture: sonifying emotions in eeg data. 2018.

[66] Jonathan Weinel, Stuart Cunningham, Nathan Roberts, Shaun Roberts, and Darryl Griffiths. Eeg as a controller for psychedelic visual music in an immersive dome environment. *EVA London 2014: Electronic Visualisation & the Arts*, 2014.

[67] Satvik Venkatesh, Eduardo Reck Miranda, and Edward Braund. Ssvep-based brain–computer interface for music using a low-density eeg system. *Assistive Technology*, pages 1–11, 2022.

[68] Makoto Iwanaga, Asami Kobayashi, and Chie Kawasaki. Heart rate variability with repetitive exposure to music. *Biological psychology*, 70(1):61–66, 2005.

[69] About neurolive. URL: https://neurolive.info/.

[70] Paul Sanden. *Liveness in modern music: Musicians, technology, and the perception of performance*. Routledge, 2013.

[71] Oliver Bown, Renick Bell, and Adam Parkinson. Examining the perception of liveness and activity in laptop music: Listeners' inference about what the performer is doing from the audio alone. 2014.

[72] Heidi Liedke. Emancipating the spectator? livecasting, liveness, and the feeling i. *Performance Matters*, 5(2):6–23, 2019.

[73] Alison Oddey and Christine White. *Modes of spectating*. Intellect, 2009.

[74] Philip Auslander. Digital liveness: A historico-philosophical perspective. *PAJ: A journal of performance and art*, 34(3):3–11, 2012.

[75] Robert S Hatten. *A theory of virtual agency for Western art music*. Indiana University Press, 2018.

[76] Roberta Hofer. Metalepsis in live performance: Holographic projections of the cartoon band 'gorillaz'as a means of metalepsis. *Metalepsis in Popular Culture*, 28:232, 2011.

[77] Zane Lowe, Cedric Bixler-Zavala, and Omar Rodriguez-Lopez. The mars volta: Zane lowe intervierw, 2022. URL: https://music.apple.com/us/playlist/the-mars-volta-the-zane-lowe-interview/pl.54f8099a4f574ad0aa12937e66bc01a7.

[78] The Editors of Encyclopaedia Britannica. Cantus firmus, Jul 2007. URL: https://www.britannica.com/art/cantus-firmus.

[79] Peter Manning. *Electronic and computer music*. Oxford University Press, 2013.

[80] Deger Ayata, Yusuf Yaslan, and Mustafa E Kamasak. Emotion based music recommendation system using wearable physiological sensors. *IEEE transactions on consumer electronics*, 64(2):196–203, 2018.

[81] Javier Jaimovich, Niall Coghlan, and R Benjamin Knapp. Emotion in motion: A study of music and affective response. In *International Symposium on Computer Music Modeling and Retrieval*, pages 19–43. Springer, 2012.

[82] Elaine Chew. On making music with heartbeats. In *Handbook of Artificial Intelligence for Music*, pages 237–261. Springer, 2021.

[83] Harold Owen. *Music theory resource book*. Oxford University Press, 2000.

[84] Russell Burton. The elements of music: what are they, and who cares. In *Music: Educating for Life. ASME XXth National Conference Proceedings*, pages 22–28. Australian Society for Music Education Parkvill, VIC, Australia, 2015.

[85] Daniel Teruggi. Technology and musique concrète: the technical developments of the groupe de recherches musicales and their implication in musical composition. *Organised Sound*, 12(3):213–231, 2007.

[86] Joel Ryan. As if by magic.

[87] Lev Manovich. Principles of new media. *Mediamatic. net: http://www. mediamatic. net/5971/en/principles-of-new-media–1*, 2000.

[88] Lev Manovich. *The language of new media*. MIT press, 2002.

[89] Jamshed Bharucha and Carol L Krumhansl. The representation of harmonic structure in music: Hierarchies of stability as a function of context. *Cognition*, 13(1):63–102, 1983.

[90] Ian Quinn. Tonal harmony. In *The Oxford Handbook of Critical Concepts in Music Theory*. Oxford University Press, 2019.

[91] François J. Bonnet, Bartolomé Sanson, and Beatriz Ferreyra. *Perceive, Feel, Hear...*, pages 33–38. Shelter Press, 2019.

[92] François Bonnet, Bartolomé Sanson, and Chris Corsano. *Improvisation and Resonance*, pages 75–79. Shelter Press, 2020.

[93] Philip Auslander. Lucille meets guitarbot: Instrumentality, agency, and technology in musical performance. *Theatre Journal*, pages 603–616, 2009.

[94] Brian Eno. *A year with swollen appendices: Brian Eno's Diary*. Faber & Faber, 2020.

[95] Charles B Fowler. The museum of music: A history of mechanical instruments. *Music Educators Journal*, 54(2):45–49, 1967.

[96] George Brock-Nannestad and Jean-Marc Fontaine. Early use of the scott-koenig phonautograph for documenting performance. *Journal of the Acoustical Society of America*, 123(5):3802, 2008.

[97] Julia Perfan and Guillermo del Toro. 2018 golden globes press conference, 2018.

[98] Jessica Aslan and Emma Lloyd. Breaking boundaries of role and hierarchy in collaborative music-making. *Contemporary Music Review*, 35(6):630–647, 2016.

[99] Clément Canonne. Rehearsing free improvisation? an ethnographic study of free improvisers at work. *Music Theory Online*, 24(4), 2018.

[100] Derek Bailey. *Improvisation: Its nature and practice in music*. Da Capo Press, 1993.

[101] Gerald Abraham. *The tradition of Western music*. Univ of California Press, 1974.

[102] William P Malm. *Traditional Japanese music and musical instruments*. Kodansha International, 2000.

[103] Luciana Galliano. *Yogaku: Japanese music in the 20th century*. Scarecrow Press, 2002.

[104] Takie Sugiyama Lebra. The cultural significance of silence in japanese communication. 1987.

[105] Murasaki Shikibu. *Genji monogatari*. Tuttle Publishing, 2012.

[106] Anne Draffkorn Kilmer and Miguel Civil. Old babylonian musical instructions relating to hymnody. *Journal of Cuneiform Studies*, 38(1):94–98, 1986.

[107] Harvey N Roehl. Player piano treasury: The scrapbook history of the mechanical piano in america as told in story, pictures, trade journal articles and advertising. *(No Title)*, 1961.

[108] Patrick Feaster. The origins of ethnographic sound recording, 1878-1892. *ReSOUND*, pages 1–8, 2001.

[109] Bruce Ellis Benson. The improvisation of responding to the call. *Philosophy of Improvisation: Interdisciplinary Perspectives on Theory and Practice*, page 4, 2021.

[110] Tim Perkis, John Bischoff, Jim Horton, Rich Gold, Paul DeMarinis, and David Behrman. *The League of Automatic Music Composers, 1978-1983*. New World Records, 2007.

[111] Brett Boutwell. The league of automatic music composers, 1978–1983. with john bischoff, jim horton, tim perkis, david behrman, paul demarinis, and rich gold. new world records 80671-2, 2007. *Journal of the Society for American Music*, 3(2):263–264, 2009.

[112] Nicolas Collins. Composers inside electronics: Music after david tudor. *Leonardo Music Journal*, 14(1):iv–1, 2004.

[113] URL: `https://www.twohp.com/systems/synth-voice`.

[114] URL: `https://www.twohp.com/systems/drum-machine`.

[115] URL: `https://www.analoguesystems.co.uk/index.php/keyboards/the-french-connection`.

[116] Debbie Poyser & Derek Johnson. Spawn, Dec 2023. URL: `https://www.soundonsound.com/reviews/analogue-systems-spawn`.

[117] Gordon Reid. Analogue systems french connection, Nov 2023. URL: `https://www.soundonsound.com/reviews/analogue-systems-french-connection`.

[118] Danny Hynds, George Chernyshov, Dingding Zheng, Aoi Uyama, Juling Li, Kozue Matsumoto, Michael Pogorzhelskiy, Kai Kunze, Jamie Ward, and Kouta Minamizawa. Innermost echoes: Integrating real-time physiology into live music performances. In *Proceedings of the Eighteenth International Conference on Tangible, Embedded, and Embodied Interaction*, pages 1–12, 2024.

[119] Jiawen Han, George Chernyshov, Moe Sugawa, Dingding Zheng, Danny Hynds, Taichi Furukawa, Marcelo Padovani Macieira, Karola Marky, Kouta Minamizawa, Jamie A Ward, et al. Linking audience physiology to choreography. *ACM Transactions on Computer-Human Interaction*, 30(1):1–32, 2023.

[120] David Rosenboom. Propositional music: On emergent properties in morphogenesis and the evolution of music. part i: Essays, propositions and commentaries. *Leonardo*, pages 291–297, 1997.

[121] Ernst Kurth and Kurth Ernst. *Ernst Kurth: selected writings*. Number 2. Cambridge University Press, 1991.

[122] Franćois-Jacques Bonnet, Bartolomé Sanson, and Lee Gamble. pages 39–49. Shelter Press, 2023.

[123] Dušan Bogdanović, Xavier Bouvier, and David Rosenboom. *Proportional Music of Many Nows*, pages 121–142. Les Éditions Doberman-Yppan, 2018.

[124] David J Hargreaves, Raymond MacDonald, and Dorothy Miell. How do people communicate using music. *Musical communication*, 1:1–26, 2005.

[125] Roger A Kendall and Edward C Carterette. The communication of musical expression. *Music perception*, 8(2):129–163, 1990.

[126] Moe Sugawa, Taichi Furukawa, George Chernyshov, Danny Hynds, Jiawen Han, Marcelo Padovani, Dingding Zheng, Karola Marky, Kai Kunze, and Kouta Minamizawa. Boiling mind: Amplifying the audience-performer connection through sonification and visualization of heart and electrodermal activities. In *Proceedings of the Fifteenth International Conference on Tangible, Embedded, and Embodied Interaction*, pages 1–10, 2021.

[127] Qianqian Mu, George Chernyshov, Ziyue Wang, Danny Hynds, Dingding Zheng, Kouta Minamizawa, Dunya Chen, Atsuro Ueki, Masa Inakage, and Kai Kunze. Imageflowing-enhance emotional expression by reproducing the vital signs of the photographer. In *ACM SIGGRAPH 2022 Emerging Technologies*, pages 1–2. 2022.

Appendices

A. Interview Statements

Several open-ended statements were provided by experts in the fields of music, performance, composition, and sound art. These artist practitioners were asked to simply give their open and honest thoughts in regards to the proposed *Sonic Vessels* method and the subsequent performance works which arose from it. These statements were discussed in 6.4. Here are provided the full unedited statements from these experts, in alphabetical order.

A.1 Ryo Harada: Director (Lader Production), Spatial Audio Expert

Original Japanese Version

”3人の演奏者とロボット箏のパフォーマンスは、まずショウとして、バランスの良い楽曲展開を楽しめるものでした。コンダクター、企画者であるDanny氏自身による、シーケンサーによる楽曲に音楽的なメリハリがあるため、作品性を損なわずにロボットによる自動生成による演奏を取り入れたパフォーマンスになっていたと思う。

生理センシングに関しては、来場者全体のデータをインプットしながら、自動生成の演奏にフィードバックしていたという概念については理解できたが、私自身はオーディエンスとしては仕組みとパフォーマンスの関係性を理解して鑑賞するには至らなかった。ただし、熟達した和楽器の演奏者たちのパフォーマンスが、ロボット箏の演奏の影響を受けて変化していることについては、体感することができた。

一般的に、ステージ上の演奏者の聴衆との相互作用については、ジャンルによって度合いは異なってくる。ジャズやDJパフォーマンスなど、即興要素の強いジャンルもあれば、クラシック音楽のようなプリプログラムされた

ジャンルもある。またゴスペルの集会など、参加者全体が一体化して一つの空間を作り上げるものもある。今回のパフォーマンスは、演奏者と聴衆の相互作用、演奏者同士の相互作用、ロボット箏と演奏者の相互作用、それぞれに対してユニークなアプローチをしていたと思う。”

English Translation

”The performance by the three performers and the robot Koto was, first and foremost, an enjoyable show with well-balanced musical development. I believe that the integration of the robot's automatically generated performance did not detract from the playability of the piece. This was likely due to the sequenced music by Danny, the conductor and planner himself, which was infused with musical energy and vitality.

Regarding physiological sensing, while I grasped the concept of feeding back audience data into the auto-generated performance, as an audience member, the connection between this mechanism and the actual performance was not entirely clear to me. Nonetheless, it was fascinating to experience how the performances of the skilled Japanese instrumentalists evolved under the influence of the robot koto.

In general, the level of interaction between the stage performers and the audience differs across musical genres. Some genres, like jazz and DJ performances, are heavily improvisational, while others, like classical music, are more scripted. Then there are forms like gospel gatherings, which bring everyone together to forge a collective ambiance. This performance seemed to uniquely navigate these paradigms, fostering interaction among the audience, the performers, between the robot koto and the human artists.”

A.2 Bobby Hawk: Composer, Recording Artist (Taylor Swift, Diana Ross, Bleachers, The 1975)

”Tonight, I had a performance where the music was completely improvised. If we were able to make use of Danny's reading of the audience, not only would we be able to improvise the music but we could also change it in a moment's notice depending on how they are reacting to the music. This kind of technology would

be invaluable and would make the user experience, both for the audience and for the musicians, priceless. Just this week alone, I have performed at the Whitney Museum and have had performances all around New York City at various venues. Being able to hand out the necessary tools to gauge the audiences reaction would be not only hopeful but something that the museum would find so fascinating. It could become its own exhibit. Gaining a better understanding of this method has opened me up to new areas of my expressive possibilities and I look forward to seeing what new ideas will be inspired by this approach in my work and the works of my colleagues. In closing, I can't wait to use these tools to heighten the experience for the audience and for the ensemble in real time."

A.3 Evan Marien: Bassist, Composer, Producer (Allan Holdsworth, Tigran Hamasyan, Elliot Moss)

"Danny Hynds' *Sonic Vessels* method introduces a refreshing and avantgarde perspecive to the realm of performance and composition. One of the key advantages of Sonic Vessels is its adaptability to a wide range of musical genres and styles. Whether in classical, contemporary, or experimental settings, this method provides performers with a versatile toolkit to enhance their creative expression. The incorporation of electronic elements adds a layer of complexity and richness to the performance, allowing skilled musicians to push the boundaries of their artistry.

Furthermore, *Sonic Vessels* facilitates a collaborative and interactive approach to composition and performance. The method encourages performers to explore improvisation and real-time manipulation of sound, fostering a dynamic and engaging musical experience for both the musicians and the audience. This interactive aspect not only enhances the performer's connection to the music but also creates a unique and memorable experience for those witnessing the performance.

In conclusion, I am confident that Danny Hynds' *Sonic Vessels* method has the potential to revolutionize the way skilled performers approach their craft. Its fusion of traditional and electronic elements, adaptability across genres, and emphasis on collaboration make it a valuable addition to the contemporary musical landscape. I wholeheartedly recommend the exploration and incorporation of Sonic Vessels to any skilled performer seeking to expand their artistic horizons."

A.4 Akira Sakamoto: Bassist, Interviewer

"It goes without saying that the new technology has not only the industrial but also the artistic influences. The new technology has the potential to inspire artists to create unprecedented forms or genres of art. Mr. Hynds' current project combines the latest wifi-technology, the tried-and-tested analog synthesizer and some robotics. Also, an erhu player, a koto player and Mr. Hynds himself plays some pre-composed parts and improvises along the way.

The most interesting aspect of the project to me is that the excitement of the audience is fed back to the players via a specially designed computer system. Usually, the excitement of the audience is expressed in the physical way such as yells, applause, moving bodies, etc., which are the directly emotional feedback to the performers but won't control the instruments that the performers play. On the other hand, Mr. Hynds' system allows the audience, even subconsciously, to influence on the instrument somewhat directly. This can add some sort of randomness to the overall performance, and add some element of the chance operation.

For the second performance, the sensor system was not used, but instead a bunch of compact cassette tape players and a couple of analog video players and television sets were employed. To me, they functioned as generators of random elements effectively to compensate for the lack of the sensor system. Each cassette player was hung from the ceiling with a thread and rotated randomly, which created some panning/phasing effects and an interesting ambience. There was no erhu player, but the use of Ondes Martenot style keyboard by Mr. Hynds compensated for the lack of erhu, an instrument that can play portamento, nicely.

I found the overall concept of Mr. Hynds' project very promising and full of potentiality. The performance will be more interesting when the players are more accustomed to react to the randomly generated elements around them and open up themselves more to improvise. Also, there should be more ways to control analogue synthesizer modules to generate much more varied sounds."

A.5 Claire Taylor: Adjunct Instructor of Music (Millikin University), Principal Bassoonist (Millikin-Decatur Symphony Orchestra)

"Highly skilled musicians, whatever the genre, must be alert to the presence and activity of their colleagues. One of the great joys in chamber music is when attention to each other allows us to "improvise" our rubato, ornamentation, intonation and dynamic adjustments. More explicitly improvisatory styles, such as jazz and rock, require even more flexibility and skill in order to bring the music to a climax or satisfying ending. Danny Hynds' *Sonic Vessels* method of performance/composition would allow skilled performers to expand their performance by adding a new dimension to this system. The presence and excitement of our fellow performers or audience members made tangible would allow for more unexpected and diverse musical interpretations. It could also provide a structure for highly skilled musicians that possess these skills of sensitivity but are not as comfortable with improvisation to approach it. Additionally, it could be an avenue for less experienced musicians to ponder and learn these important skills of responding to others, and provide a way for teachers and students to discuss this difficult skill. Solo performers looking to add harmony/polyphony to a performance are currently limited to looping or playing along with tracks. This method provides a much more vital way of adding sound to a solo performance because it is truly the performer in real time making the sound. This is also true for musical groups wishing to perform together remotely-rather than relying on laying down tracks separately, where any musical response is one-sided since the previous tracks cannot change, the performers can react to each other's presence in a way that is currently not possible with remote performances.

The level and quality of audience engagement is obvious to skilled performers and actively affects the performance. Additionally, audiences want to be a part of the performance; we see this in many manifestations: acknowledging a great jazz solo with shouts and applause, dancing and singing along at a rock concert, dressing in silver for a Beyoncé concert or in tuxes and gowns for the opera. Indeed, often the experience we are seeking when attending a live performance is not only witnessing the performance on stage but witnessing it together with others. The

act of making this experience not only tangible to the performers but an active performer itself allows the audience to increase their standing in the performance and could provide increased engagement and satisfaction with the performance. It could help the audience see and understand their effect on the music and this increased buy-in could encourage them to come back again, increasing concert attendance. Compelling the performers to increase the inclusion of the audience might help them acknowledge them as their partner in the performance endeavor and improve satisfaction among performers. Also, in this increasingly digitally connected world, allowing a remote audience to affect the performance in this way allows them to experience that togetherness that normally would not be possible remotely."

B. Collaborative Works

B.1 Collaborative Works

Throughout the development of this thesis, I had the opportunity to collaborate with several of my fellow researchers on projects through which I have been able to explore and refine this conceptual framework through my own contributions to their works. I will briefly present these preliminary explorations, their impact on my concept, and my contributions to these projects in the context of my method.

Figure B.1 *Boiling Mind* by Moe Sugawa

Boiling Mind

One of the first projects I joined when I arrived at KMD was *Boiling Mind*, an on-going work which "seeks to tear down the wall between the stage and the audience in live dance works" [126]. One of the underlying concepts in this work is to use the real-time physiological data of the audience as an input for changes in the staging elements. I focused on developing an adaptive musical score which would give the dancers a clear enough musical backdrop to perform with while leaving certain elements open to change based on the incoming data. In total, we presented 15 live concerts in which this responsive sound environment was tested out. This project yielded publications in TEI and TOCHI, in addition to a collaborative grant through the Japan Science & Technology Agency, or JST.

The main focus of my sonic exploration in this work was firmly rooted in experimentation and trial and error. This was the first work in which I utilized any sort of physiological sensing or presence indication, apart from a very early work from my undergraduate studies which used proximity sensors to deploy alarmingly loud sounds in a public exhibition. With *Boiling Mind*, there were three sections of the hour-long performance where my original compositions were presented. In these works, I used a visual aid in the form of a graph showing average heartrate, EDA spikes, and RMSSD. This visual aid served as my abstract visual score, much like the methods deployed by composers of the 1960s and 1970s. The movement of the lines were interpreted not in a scientific way but instead were a visual input which would dictate the ways in which I would activate specific sounds, affect rhythmic content, and determine the start and stop times of individual soundscapes. While I would not present this as a scientific study in sonic interpretation or analysis, it was a valuable introduction to the new performative ways in which real-time presence can allow for new expressions. One of the most memorable moments was when a lone dancer, Moe Sugawa, had a solo section. When I began to see a rise in arousal levels of the audience, I would introduce more and more asynchronous rhythmic content, which then produced a more frenzied performance from her. Although the whole experience was formative in my initial explorations of what would become this presented methodology, this particular scene proved to be the most profound for me as a performer.

Figure B.2 *Frisson Waves* by Yan He

Frisson Waves

Frisson Waves was a project led by graduate Yan He in which live sensing was utilized to attempt to share and exploit the feeling of goosebumps between audience members during classical music concerts. In the final two performances of this project, I composed much of the music and designed Max/MSP environments which would sonify the incoming data from the audience in an attempt to give an auditory reference to the goosebumps feeling. In total, roughly 100 audience members were recorded and sonified throughout these two live concerts in Kawasaki and Karuizawa. This work was subsequently published in TEI and IMWUT.

This project would offer the chance to further explore new input methods of presence indication in the form of detected instances of frisson. Although this would show up in Max/MSP as an isolated trigger, much in the same was that heartbeats would arrive, I had the challenge of producing sounds in response to this that were not an isolated event for one person but an interaction between multiple audience members. To accommodate this, I created ambient washes of sound consisting of many harp notes processed through a great deal of reverb for each detection of frisson. These would allow for a more subtle and ambient response to this interaction. One one hand, this made it easier to differentiate them

from heartbeat-triggered sounds such as bass drums and individual piano notes. On the other hand, I found them to be slightly pushed to the back of the overall soundscape, which was not the intended purpose of it. In relation to my concept, this application of biofeedback helped me to develop a more nuanced approach to sound application of the audience's response, which would be further applied and refined in my later work titled *Phantom Undulations*. NEW: Specifically, the ways in which individual heart beats can be utilized to trigger events within a sonic collage without presenting the issues of either becoming too obvious or too vague. While it is not imperative for my work to present a biodata connection which is easily and directly clear, the opposite is also undesirable. The quest for finding the right balance between sonic freedom and perceptual affect began in full through my participation in this collaborative work.

Figure B.3 *Moving Photon* by Friendred Peng

Moving Photon

Another similar work which I was able to work on was a dance performance which took place at Ugly Duck in London. *Moving Photon* was envisioned and developed by Friendred Peng, a Ph.D candidate at Goldsmith's in the UK. In this work, a solo

dancer performs inside of a large LED circle controlled by six robotic arms, and six speakers are placed around the circle. I developed the live score which utilized a Max/MSP patcher that received incoming EEG and gyroscopic data from the dancer and a selection of audience members in the form of OSC messages. These message would in turn manipulate the sounds which were pre-recorded, while also triggering certain sounds if certain conditions were met.

In a similar way to *Frisson Waves*, this project introduced a new input form which forced me to expand my methods of application of biodata. In this work, much of the data that was being received by my Max/MSP patcher consisted of EEG data and gyroscope data. Although the EEG data came in at a range of roughly 0.-600., I was able to scale that down to the 0.-1. which I typically utilize. The decision to typically deal with the same range of 0.-1. came from an iterative process in which I tried first to simply use the data as-is, then moving towards a scale of 0-127 which relates more directly to MIDI numbers. Finally, I shifted my approach to a much more simple floating number range between 0 and 1. This range ended up feeling much more flexible and standard for my own compositional practice and therefore because the default range which I would use throughout my work.

In this project, the ways in which that data presents itself was significantly different from the EDA, HRV, and BPM data I was predominately using before. The same goes for the gyroscope data. With this change in biofeedback behavior, I had to shift my implementation approach. This involved the use of many individual short sounds which would be randomly selected with a limit on to how often they could be triggered. This was applied to the gyroscope data, specifically with the X-axis input. For the EEG data, I placed the different streams of incoming data to volume control of all of the possible layers of sound. By doing this, the musical results would always work in a way in which I wanted while also allowing for a constantly undulating and changing sonic dialogue. By developing the sonic layers within a fairly limited sound palette which included ambient synthesizer pads all in G minor, field recordings which had no distinct tonal properties, and rather atonal layers of metallic noise, the counterpoint between these three layers would always exist within the general sonic language which myself and Friendred decided would be most applicable for this project. Additionally, the individual

samples which were tired mostly to the gyroscope data consisted of similar sound layers, except for the fact that they were all relatively short sounds (ranging from 0.5 to 2 seconds in length). These notes layered well with the similar soundscapes being presented in the longer samples, thereby allowing a seamless blending of these sounds.

Unfortunately, I was unable to experience this work in person due to lingering flight restrictions caused by COVID-19. The responses from creator Friendred Peng, dancer/choreographer Seirian J. Griffiths, and Dr. Jamie A. Ward were all positive, with an emphasis on the immersive and dynamic qualities of the presented soundscapes and how this blend of movement, sound, and lights all worked well together.

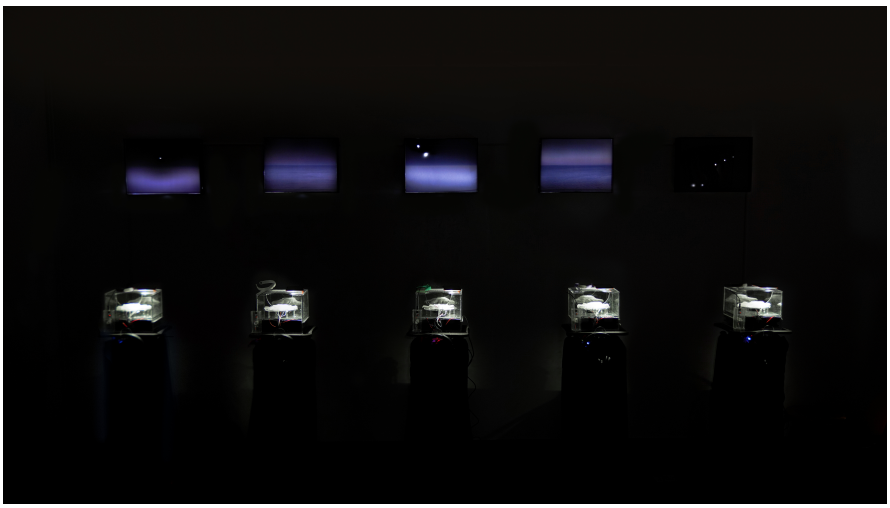

Figure B.4 *Image Flowing* by Sensen Mu

Image Flowing

Image Flowing was a project led by KMD masters student SenSen Mu. The intention of this work was to use haptics, sound, and temperature to show the emotions of the photographer at the moment they took said photographs. This project consisted of a gallery presentation (as seen in Fig.B.4) and a demo showing at SIGGRAPH E-Tech in August 2022 [127]. I developed a framework in Max/MSP which would utilized the recorded data from the photographer. I took

these data streams and fed them into a module which would look at the current value and then shift the pitch and timbre of specific oscillators to the nearest relative pitch of Bb Major. I applied the same kind of scaling on the breathing data and used this to change the overall contrast of the image so that the image would brighten and darken along with this.

With *Image Flowing*, the connection to my concept directly correlates to the deployment of *Sonic Vessels* as a flexible installation work. Prior to this exhibit, I had already shown the installation work *Sonitecture: Module 1.1* and was currently showing the first exhibit of *Innermost Echoes*. At this point, I was already in the midst of developing these works as strongly musical installations. The focus for both was centered on the sound and how it was related to the kinds of biodata were being utilized. With *Image Flowing*, I was able to explore how this sonification method could play a supporting role in a larger focus on experiencing the presence of the photographer at the time that they took said photos. In terms of my *Sonic Vessels* method, this has a deep connection to how flexible the sense of presence can be deploy in terms of sonification.

Corporeal Counterpoint

This work was a collaboration between KMD and performance artist Stelarc. During his two week visit as a Visiting Guest Lecturer, we developed a prototype performance piece which sought to explore sonification of bodily presence and gestural performative movements. In this project, I worked with Stelarc on developing the concept and created the sonic and spatial audio framework. This included an 8.2-channel audio system laid out in a way in which it surrounded the audience. Stelarc's ECG data and his location within the room was gathered as real-time data which was then sent to my Max/MSP system, allowing me to implement this presence information into my sonification system which included a Eurorack synthesizer and pre-recorded field recordings of amplified room noises from around our KMD campus building. As he moved his body around the room, these field recordings would become more or less amplified and affected by a reverb plugin, while his ECG was directly tied to the triggers, LFO speed, delay time, and wet/dry reverb mixes of Eurorack modules. In the scope of *Sonic Vessels*, I used this opportunity to focus on the spatial location and audience interaction as

a means of sonification and performative routing. With my previous *Sonic Vessels* performances, the performers remained somewhat stationary, whereas this performance allowed me to experiment with how the performer's location and proximity to/interaction with the audience could affect the gathered data.